10

III

79-10.187
CR-158447

(E79-10187) DEVELOPMENT OF A MULTI-DISCIPLINARY ERTS USER PROGRAM IN THE STATE OF OHIO. VOLUME 1: EXECUTIVE SUMMARY Final Report (Ohio Dept. of Economic and Community) 430 p HC A19/MF A01 CSCL 05B G3/43

N79-22586

Unclas
00187

FINAL REPORT ON

DEVELOPMENT OF A MULTI-DISCIPLINARY ERTS USER PROGAM IN THE STATE OF OHIO

Volume 1

EXECUTIVE SUMMARY

20900

Original photography may be purchased from
EROS Data Center

Sioux Falls, SD 57198

OHIO DEPARTMENT OF
ECONOMIC AND COMMUNITY
DEVELOPMENT

ORIGINAL CONTAINS
COLOR ILLUSTRATIONS

FINAL REPORT ON

DEVELOPMENT OF A MULTI-DISCIPLINARY ERTS USER PROGAM

IN THE STATE OF OHIO

Volume 1

EXECUTIVE SUMMARY

OHIO DEPARTMENT OF
ECONOMIC AND COMMUNITY
DEVELOPMENT

Volume 1

EXECUTIVE SUMMARY

Final Report: Development of a Multi-Disciplinary ERTS User Program in the State of Ohio

Performed for: Goddard Space Flight Center

Contract Number: NASS-22399

Date: February 5, 1977

Principal Investigator: Paul E. Baldridge
Assistant Director
Department of Economic and Community Development
P.O. Box 1001
Columbus, Ohio 43216

Program Manager: Thomas A. Martin
Program Manager
Remote Sensing Programs
Department of Economic and Community Development

Investigators:

Ohio Department of Economic and Community Development
Mr. Charles Weber

Ohio Department of Natural Resources
Mr. Gary Schaal

Ohio Environmental Protection Agency
Mr. Carl Wilhelm

Battelle Columbus Laboratories
Mr. G. E. Wurelic
Mr. J. G. Stephan
Mr. T. F. Ebbert
Mr. H. E. Smail

Bendix Aerospace Systems Division
Dr. J. McKeon
Mr. N. Schmidt

Dr. Oscar Fisch, Consultant

Mr. Stephen Gordon, Consultant

EXECUTIVE SUMMARY

OVERVIEW

This four volume document constitutes the final report of the development of a multidisciplinary Earth Resources Technology Satellite (ERTS) user program in the State of Ohio. The three original objectives of this program were to: Perform research into new applications of satellite imagery for everyday state planning and resource management functions; attempt to merge processed LANDSAT imagery with socio-economic data; and develop a statewide land inventory using LANDSAT data. The original sequence of activities was reversed during the course of the program so that the land inventory occurred first, the socio-economic/LANDSAT merger second, and the investigation of new applications third.

PROGRAM EVALUATION

In terms of program objectives, the three phases mentioned above have been completed. (1) The State of Ohio has developed a current, uniform land inventory derived, in part, from LANDSAT data. In addition, the State has the ability to convert processed land information from LANDSAT to OCAP data files. OCAP is an acronym for the Ohio Capability Analysis Program developed by the Ohio State University and the Ohio Department of Natural Resources. OCAP is a computer information and mapping system comprised of various programs used to digitally store, analyze, and display land capability information. OCAP can provide tailored land information to users economically. (2) The State has acquired considerable experience in its attempts to merge LANDSAT data with socio-economic information. Indications

are that more accurate processing of LANDSAT data could lead to reasonably accurate, useful land allocation models. (3) Efforts to investigate new applications of satellite imagery have been moderately successful, suggesting that it is feasible to use LANDSAT information for such varied purposes as mineral exploration, pollution analysis, land use mapping and resource inventory. Summaries of individual program phases follow.

VOLUME 3: DEVELOPMENT OF A STATEWIDE LAND USE INVENTORY

This volume describes the procedure used by the State and Bendix Aerospace Systems Division to generate a land use inventory using LANDSAT. Basically, the procedure involves data collection and processing, categorization and location of data, conversion of LANDSAT tapes to OCAP format, and verification of imagery categories. Data collection involved acquisition of good quality LANDSAT imagery as well as training materials for image interpretation such as aerial photos, maps and localized ground information. Data were processed to produce interpreted land use information on computer compatible tapes (CCT's). Ground information was located and interpreted for comparison to the CCT's. Information was thus "categorized" to develop a uniform set of land categories for further interpretation. The process of converting LANDSAT data to OCAP format involved the location of pertinent boundaries by OCAP digital format, the conversion of LANDSAT categories to land use files (again, in OCAP format), and the creation of LANDSAT/OCAP county files. Files were analyzed statistically, in terms of acreages and percentages of land use classes by political jurisdiction. Two studies were used to verify the land cover files. In the first of these, files were verified across the State using a sample of 94 selected areas. Results showed that the

land use files were 80% accurate overall. The second study was much more localized and intensive. Accuracy levels of this intensive study were significantly lower than those of the statewide study. This disparity suggests the need for further study by the State to improve the accuracy of land use information, both in terms of information processing and categorization.

VOLUME 3: THE OHIO LAND ALLOCATION MODEL

The purpose of this project was to develop a set of land use models relating socio-economic characteristics to changes in land use as measured by interpretation of LANDSAT data. The State contracted with two consultants for this phase of the program, and the consultants initiated a number of activities. These included reviews of: land use models developed for other areas, data available for the current modeling effort, and potential uses of LANDSAT imagery in land use studies. Cross sectional statistical models were developed for residential, commercial, industrial and agricultural uses. Each of these models utilized assessed value of land and number of parcels with respect to population and employment levels. The agricultural models were revised to incorporate data related to agricultural production. Results indicate that the LANDSAT data for Ohio are not of high enough accuracy to be used in a modeling framework. However, one category of LANDSAT data (Urban Residential) does form a significant relationship with socio-economic data. This indicates that a more accurate LANDSAT data base could lead to simulation models similar to those developed in this phase.

VOLUME 4: DEVELOPMENT OF NEW APPLICATIONS

The State contracted with Battelle Columbus Labs to develop new ap-

plication possibilities and to promote user awareness of LANDSAT data for economic, resource, and community development interests in Ohio. Four projects--Linear Analysis, Lake Erie Sedimentation, Urban Land Use and Woodlands Analysis--were undertaken using LANDSAT imagery, LANDSAT CCT tapes, SKYLAB imagery, high and low level aircraft imagery and ground information. These four projects were selected on the basis of previous investigation of LANDSAT flexibility, degrees of operational feasibility, and usefulness to the State. Summaries of the four projects follow.

LINEAR ANALYSIS is a method of identifying linear and curvilinear topographic features which may have significance for mineral exploration activities. The procedure involves interpretation of LANDSAT imagery and aerial photography. Results of the analyses indicated that it is feasible to map linear and curvilinear features in Ohio utilizing various interpretation techniques on LANDSAT imagery. Features identified by linear analysis should be studied to determine mineral potential.

The LAKE ERIE SEDIMENTATION ANALYSIS project set out to demonstrate that repetitive, multispectral LANDSAT data could identify, measure and model changes in sediment loadings in Lake Erie. The project was hampered by the lack of sediment measurements consistent with LANDSAT overpasses. Consequently, LANDSAT imagery could not be verified by ground measurements, and no conclusive results were obtained.

The URBAN LAND USE project involved a comparison of high altitude aerial data with LANDSAT data for Columbus and Franklin County, Ohio. The purpose of this comparison was to assess the use of LANDSAT data for inventory and mapping of land uses. The results suggest that LANDSAT data can be used effectively in non-urban areas or for selected planning interests, such as monitoring growth trends, in urban areas.

The WOODLAND ANALYSIS was designed to determine if high level aerial color infrared imagery could be used in conjunction with LANDSAT imagery to provide detailed information concerning type and condition of timber stands in Ohio. Emphasis was placed on identification of woodland boundaries, stand composition, stand maturity, cut and reseeded areas and tree stress. The results suggest that it is feasible to inventory forestlands in the State utilizing LANDSAT data in concert with extensive aircraft and ground truth data.

FINAL REPORT ON

DEVELOPMENT OF A MULTI-DISCIPLINARY ERTS USER PROGRAM

IN THE STATE OF OHIO

Volume 2

DEVELOPMENT OF A
STATEWIDE LAND USE INVENTORY

OHIO DEPARTMENT OF
ECONOMIC AND COMMUNITY
DEVELOPMENT

Volume 2

DEVELOPMENT OF A STATEWIDE LAND USE INVENTORY

FINAL REPORT:	Development of a Multi-Disciplinary ERTS User Program in the State of Ohio
PERFORMED FOR:	Goddard Space Flight Center
CONTRACT NUMBER:	NAS5-22399
DATE:	September 5, 1977
PRINCIPAL INVESTIGATOR:	Paul E. Baldridge Assistant Director Department of Economic and Community Development P.O. Box 1001 Columbus, Ohio 43216
PROGRAM MANAGER:	Thomas A. Martin Program Manager Remote Sensing Program Department of Economic and Community Development
INVESTIGATORS:	Volume Two Ohio Department of Natural Resources Mr. Gary Schaal Ohio Environmental Protection Agency Mr. Carl Wilhelm Bendix Aerospace Systems Division Dr. J. McKeon Mr. N. Schmidt

TABLE OF CONTENTS

12

TABLE OF CONTENTS (Cont'd.)

13

LIST OF TABLES

14

LIST OF ILLUSTRATIONS

INTRODUCTION

This volume reports the contract efforts to develop an operational land use inventory. The most recent statewide, comprehensive inventory of Ohio's land uses was prepared in 1965. This first statewide land use inventory was developed from the United States Geological Survey 7-1/2 minute quad sheets prepared for Ohio Between 1958 and 1964. This 15 year old inventory is, in fact, a generalized summary of Ohio land uses as they existed in 1960.

The entire inventory project took nearly two (2) years to reach completion. The twelve (12) land use categories were displayed for the entire state on a map sheet at a scale of approximately 1:500,000. Since data had been inventoried on the basis of county boundaries, nine (9) regional maps, displaying the twelve (12) categories for groups of counties, were prepared at a scale of 1:250,000. In addition, a report entitled "Use of Land in Ohio", which analyzed the data and disaggregated the twelve categories into the original 25, was published as an extension of the maps.

The generalized 1960 Ohio Land Use Inventory represented a major state undertaking using one of the first HUD 701 planning grants provided to the state. The motivation for this project came from a general desire to acquire an overall picture of land use in the state. In effect, the project was research oriented with the small scale maps representing the primary objective and product.

The expanding scope of State planning as reflected in a wide variety of new planning programs, has generated the need for an accurate, up-to-date comprehensive Ohio land use inventory. The scope of State planning in Ohio is briefly illustrated by the following examples:

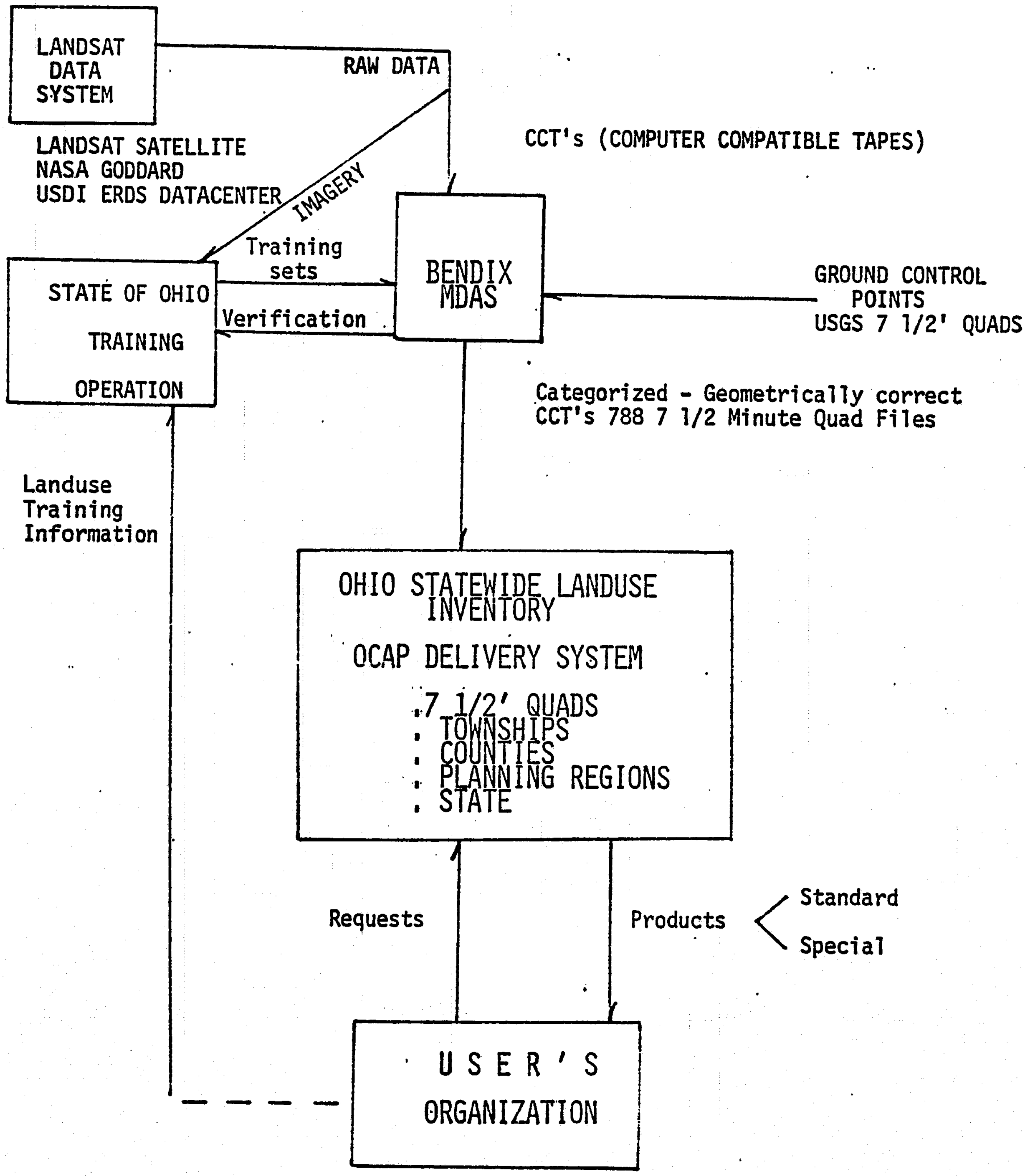
* The Coastal Zone Management Act which requires coastal states (including the Great Lakes) to prepare detailed management strategies for shoreland areas.
* The expanded land use requirements of the HUD 701 program which now mandate the preparation of statewide land use programs.
* The 208 Water Quality planning process, which requires significant amounts of land use data as input into the determination of quality and quantity of storm water run-off and nutrient flow into water ways.
* The technical planning assistance role of state government in Ohio has focused upon the dissemination of basic planning data such as a land use inventory.
* The reclamation of strip mined lands is mandated by Ohio 1972 Strip Mine Legislation. The development of an overall strategy for reclamation of some 346,000 acres requires the availability of detailed land use data. This program will be carried out using a portion of the excise tax on the severance of Ohio minerals.
* The development of statewide land use and growth policies require a land use inventory as a framework for

decision making. Pending legislation in Ohio would focus considerable attention on the revamping of Ohio's land use planning law.

* Public concern over the preservation of agricultural land, the haphazard expansion of urban areas and the misuse of Ohio's land resources, have begun to generate increasing pressure for meaningful land use plans which accurately protray present and future patterns of use.

Due to the real need of the State to prepare land use inventories, and the potential seen in the application of LANDSAT data, a protion of this contract was used to develop the procedure and system for generating and delivering land use information to users in the State of Ohio. Figure 1 provides a diagram of the overall view of the program.

Figure 1.



OVERALL VIEW STATEWIDE LANDUSE

INVENTORY PROGRAM

CHAPTER II-I

DATA COLLECTION AND TRAINING INFORMATION

Data Collection and Cataloging

The initial phase of study design implementation is the collection of appropriate data. The primary data in this case was spectral image data from LANDSAT. Reports of LANDSAT image quality that had exceeded predetermined quality criteria were received weekly by the state from the EROS Data Center. Those images that did surpass criteria were automatically assessed and usually were received by the state in three to four weeks. When the images were received, they were viewed to determine if they were completely cloud and haze free.

In order to facilitate the storage and review of LANDSAT image data, a very simple system of image identification, documenation and filing was initiated. Within each satellite cycle, the pass covering the eastern edge of the Ohio occurred on day one of the cycle. The next pass west occurs on day two and so forth until the west edge of the state was covered in the fourth pass on the fourth day. Each pass provided three to four overlapping scenes covering the state from north to south.

Because of the stability of this pattern, it was easy to establish a track (pass) and scene (north south sequence of scenes) numbering system that immediately identifies the data. Figure 2 shows the identifying system.

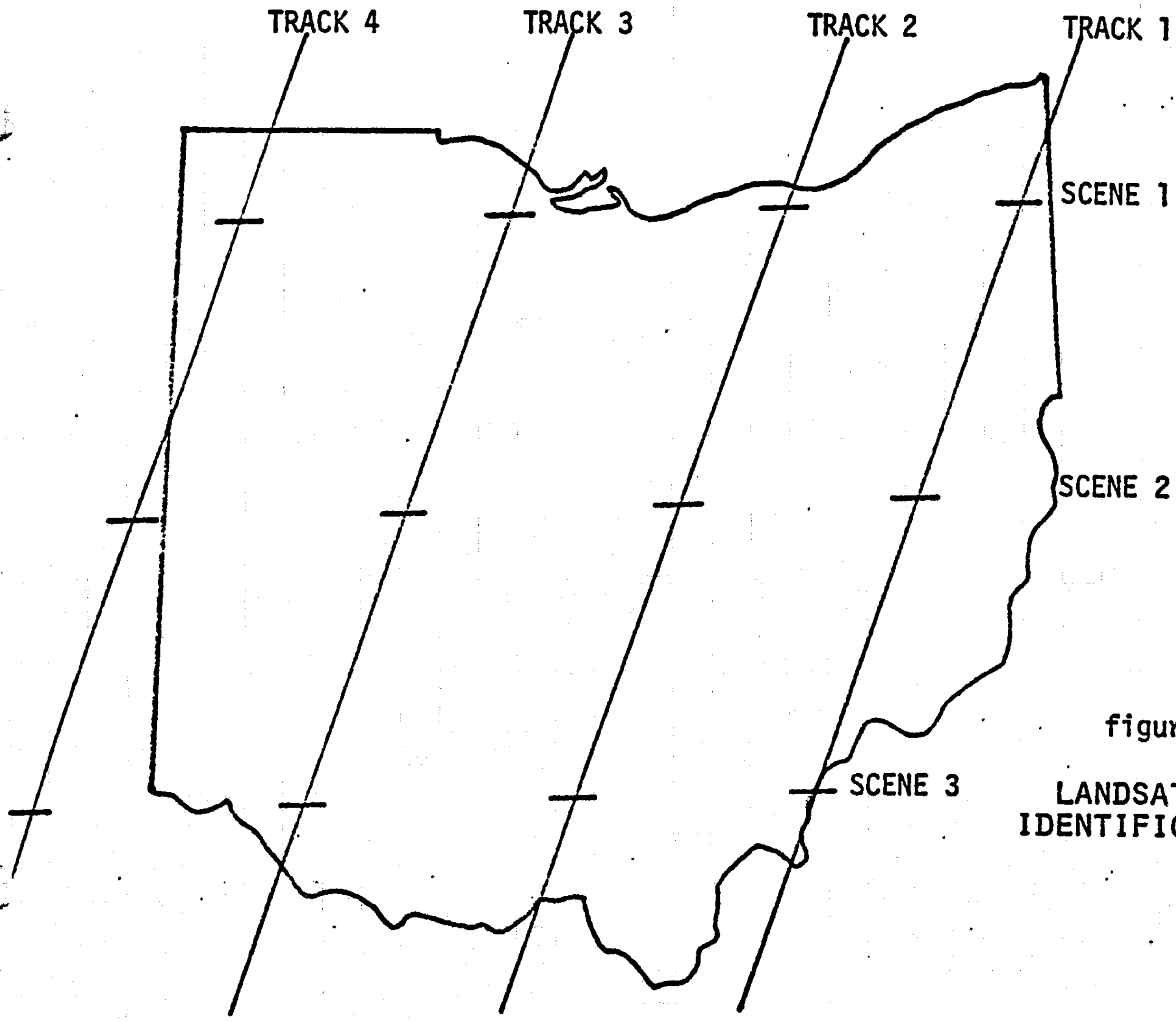


figure 2

LANDSAT IMAGE IDENTIFICATION SYSTEM

figure 3

CORRESPONDING OHIO/WORLDWIDE LANDSAT IMAGE IDENTIFICATION

LEGEND

T 4 S 1
P 22
R 31

Worldwide I.D. Path and Row

Ohio I.D. Track and Scene

T4 S1 P 22 R 31	T3 S1 P 21 R 31	T2 S1 P 20 R 31	T1 S1 P 19 R 31
T4 S2 P 22 R 32	T3 S2 P 21 R 32	T2 S2 P 20 R 32	T2 S2 P 19 R 32
T4 S3 P 22 R 33	T3 S3 P 21 R 33	T3 S3 P 20 R 33	T3 S3 P 19 R 33

21

A data log book was prepared with each page representing a cycle, and space provided for logging each track and scene entry illustrated in Figure 4. In this way, coverage was immediately apparent over time and location, plus the data adequacy.

Data Review and Selection

Because of the strict criteria, most scenes were unacceptable for processing and the state was still not covered as the late fall and winter months approached. Winter data is seasonally poor for land cover interpretation. Marginal scenes were selected, although from a complete search of the EROS LANDSAT data base (Jan. 22, 1975 forward) along with the good July 1975 data in a conference with the Bendix Aerospace Division. Due to the time factor, Computer Compatible Tapes (CCT's) were ordered from the EROS Data Center in January - February of 1976. In April of 1976, during cycle 24 of LANDSAT II, four good days of data collection provided data to substitute for the marginal scenes. The only exception was that scene covering the Cleveland vicinity.

The state decided to proceed with the data set as it stood in June 1976 and categorical processing was begun.

LANDSAT scenes processed from the best available coverage are shown in Table 1. The scene coverage is shown in Figure 5.

FIGURE 4
DATA ACQUISITION STATUS
LANDSAT II
(SAMPLE)

Cycle ___________

	/ / Track 4	/ / Track 3	/ / Track 2	/ / Track 1
Scene 1	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15411	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15353	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15301	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15242
Scene 2	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15413	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15355	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15303	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15244
Scene 3	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15415	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15362	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15305	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15250
Scene 4	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15420	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15364	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15310	Bands 4 5 6 7 Quality _ _ _ _ Com ________ ________ 15252

TABLE 1

LANDSAT scenes processed for the Ohio State inventory

Reference Number 1	LANDSAT Scene Number	LANDSAT Scene Date
1A	2190-15410	31 July 1975
1B	2442-15372	8 April 1976
2A	2189-15325	30 July 1975
2B	2189-15355	30 July 1975
2C	2441-15320	7 April 1976
3A	2278-15283	27 October 1975
3B	2188-15300	29 July 1975
3C	2440-15262	6 April 1975
4A	2439-15195	5 April 1976
4B	2439-15201	5 April 1976
4C	2439-15204	5 April 1976
OCD	1337-15475	25 June 1973

Reference number was generated internally Bendix Aerospace

(Change detection in Franklin Co. area processed for merge with socio economic data.)

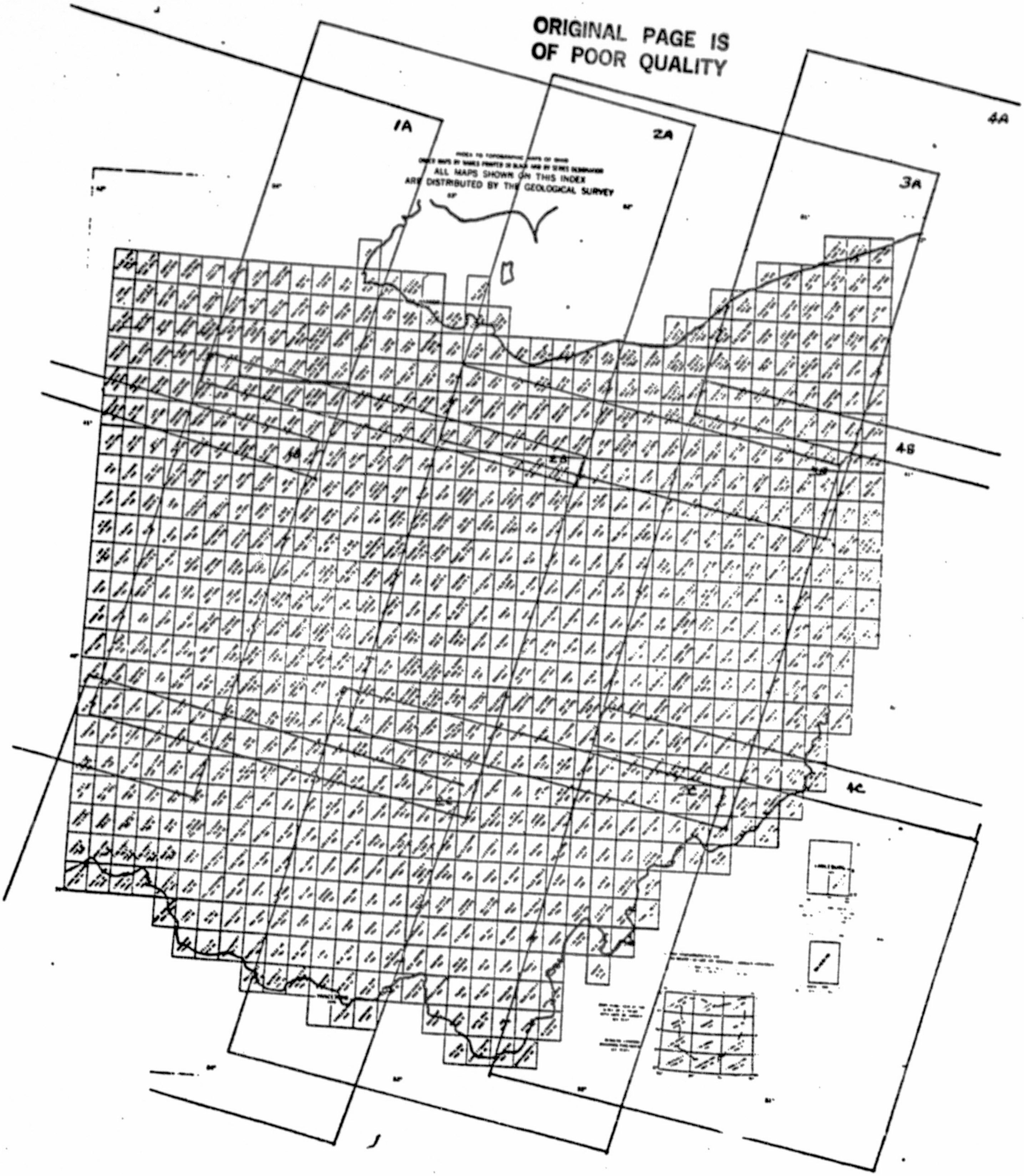


Figure 5. Location Map of Landsat Coverage

ORIGINAL PAGE IS
OF POOR QUALITY

Developing Training Information

In a statewide program applying a new and generally unfamiliar technology, training the machine processing system becomes a problem, and a portion of the overall results of the program must be a function of the success of the training process. Flow of the technical program is shown in Figure 1. A total evaluation of this program may demonstrate that classification accuracy is spatially related to the distribution of the training areas.

Two approaches were taken. First, train with available aerial photography (small and large scale black and white and color infrared) in addition to other available maps and information. Second, an effort to develop an awareness at the local and regional level of training requirements of machine processing and to utilize that awareness, to obtain training information.

Information from this second approach was used in the southwest portion of the final inventory; however, a complete and proper implementation and evaluation was not made. Its presentation is made because of the attractiveness of (a) obtaining a large amount of training information without increasing the small state staff and (b) involving the probable final user in producing and utilizing the product. This second approach is outlined in the Appendix as stimulus for further development.

Use of Available Data

The Ohio Department of Economic and Community Development (DECD) provided several different types of ground truth material. The ground truth data

included: selected aerial photography covering portions of Columbus, Cleveland, Cincinnati, Akron, Toledo and other regions throughout the State, regional land use maps near Cleveland, and training area forms which were the result of a specific ground truth identification program developed by DECD. LANDSAT images (band 5 and 7, at 1:1,000,000) were provided for each scene, and assisted in the selection of categorization coverage for each part of the state from the appropriate scenes. In addition, a set of USGS 7-1/2 minute quadrangle maps (1:24,000) were used for ground truth and ground control points.

Of the various types of training area material provided by the State, the most useful, listed in respective order, were:

a) Aerial photography - Color IR as flown by NASA in August 1975 at an altitude of 65,000 feet.

b) Other aerial photography - black and white over several specific areas of the State.

c) LANDSAT images - black and white at scale of 1:1,000,000 bands 5 and 7.

d) Ohio statewide land use inventory training area package.

e) USGS 7-1/2 minute quadrangle maps for the entire State.

g) Additional soil maps, road maps and other Bendix materials.

Various combinations of these training materials were used to categorize the eleven LANDSAT scenes covering the entire state.

CHAPTER II-2

MACHINE PROCESSING OF LANDSAT DATA

LANDSAT Data Processing Steps

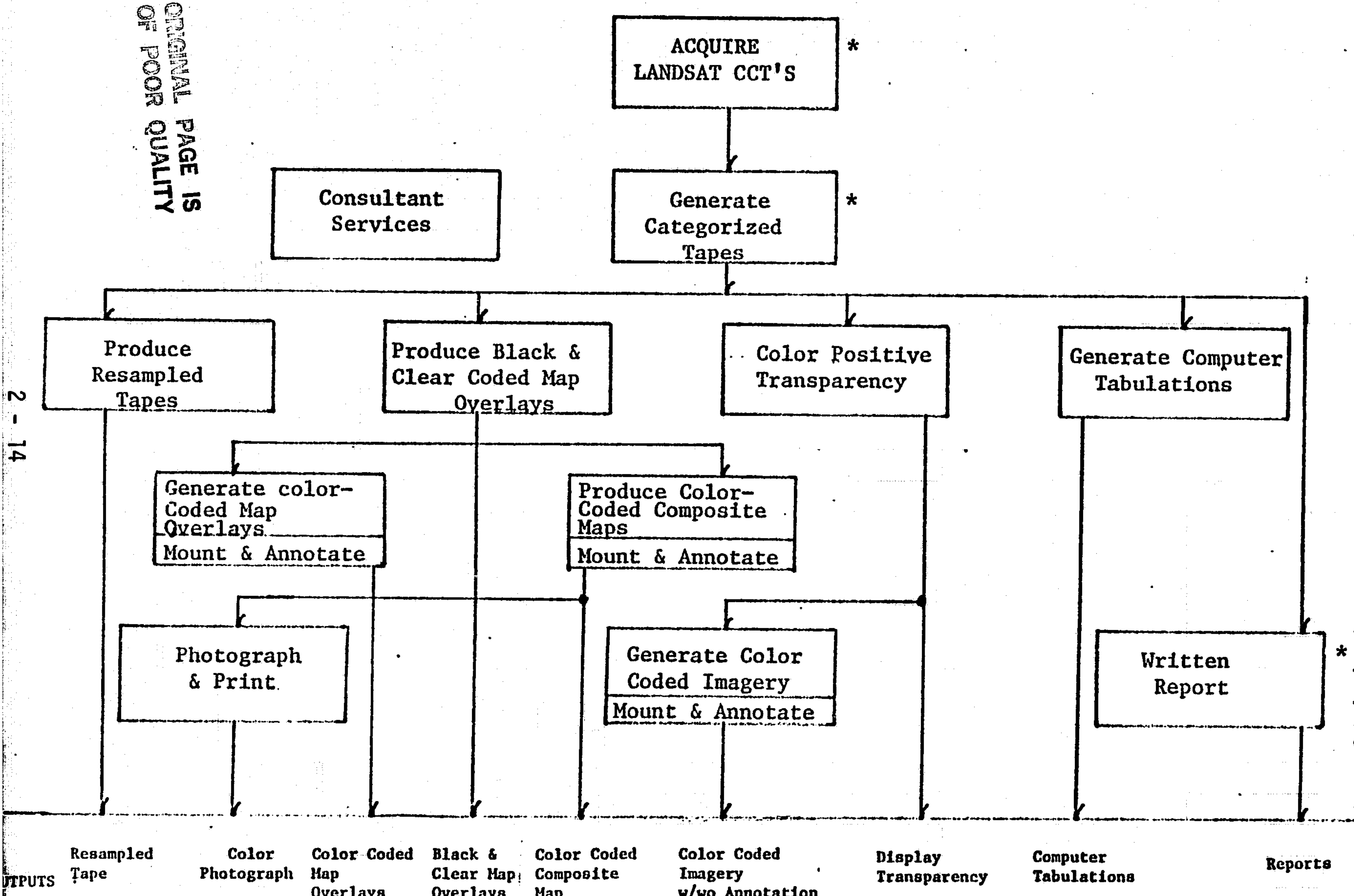
A number of processing steps were followed to produce the computer tape file products required for this project. Figure 6 shows the general sequence of steps and denotes which steps were taken. The following paragraphs describe these and other intermediate steps.

Generation of Categorized Tapes

For this investigation, LANDSAT CCT's were acquired by the State of Ohio and processed on the Bendix Multispectral Data Analysis System (MDAS) to produce interpreted land cover data. Information provided by the State of Ohio was used to locate "training areas" nominally 20 to 40 acres in size which were representative of each category.

These areas of ground truth data were located on the LANDSAT CCT's by viewing the taped data on the M-DAS TV monitor. The coordinates of the training areas were designated to the computer by placing a cursor over the desired area and assigning a training area designation, category code, and color code. Several training areas, typically 20 to 50 pixels in size, were picked for each category, with each pixel corresponding to a ground coverage of 57 x 79 m. The color code was used in later playback of the tapes when the computer-categorized data are displayed in the designated colors.

FIGURE 6
LANDSAT DATA PROCESSING STEPS
AND OUTPUT PRODUCTS



* Shading denotes steps or products included for this investigation

29

The LANDSAT spectral measurements within the training area boundaries were edited by the computer from the CCT, and processed to obtain a numerical descriptor (computer-processing coefficients) to represent the spectral characteristics of each target category. The descriptors included the mean signal and standard deviation for each LANDSAT band and the covariance matrix taken about the mean. The descriptors were then used to generate a set of processing coefficients for each category. In multivariate categorized processing, the coefficients are used by the computer to form a linear combination of the LANDSAT measurements for each pixel. The variable produced has an amplitude which is associated with the probability that the unknown pixel measurements belong to the particular target category sought. In categorical processing, the probability of a LANDSAT pixel arising from each one of the different target categories of interest is computed for each pixel and a decision, based on these computations, is reached. If all the probabilities are below a threshold level specified by the operator, the computer will decide that the category viewed is unknown (uncategorized).

Once the analyses were completed for the cover types of interest, the MDAS computer used the LANDSAT measurements from these training areas to categorize each one acre picture element (pixel) with the state. The categorization effort resulted in a "categorized tape". On this new tape, a digital code is used to represent the interpreted land-cover categories. Special software was developed for this project, at no cost to the contract, to merge the category groups from each of the eleven scenes into one common category coding. The data was then reformatted to create a new merged categorized tape containing the standard category coding for the entire state.

Geometric Control

After categorization and prior to producing the tape products, the LANDSAT data was geometrically controlled. There are three basic steps involved in producing coefficients for the correction of LANDSAT data. The first step consists of automatic retrieval of the latitude and longitude of carefully selected ground control points from a map through a digitizing process. The criteria for the selection of these ground control points includes ease of identification and accuracy of location. Examples of ground control points include confluence of rivers, intersection of roads, bridges over river, and pointed shoreline and coastal features. The 7-1/2 minute quadrangle maps were used for these ground control points.

The second step consists of converting the latitude and longitude of these ground control points to LANDSAT coordinates, using a theorectical transformation derived from known and assumed spacecraft parameters such as heading, scan rate, and altitude, and from a knowledge of earth rotation parameters. The LANDSAT coordinates and transformation matrices thus obtained are approximate, based on the use of the nominal spacecraft parameters. The approximately-derived LANDSAT coordinates and transformation are used, however, to identify the actual LANDSAT coordinates associated with the ground control points. To accomplish this, the coordinates of a ground control point are input to the Bendix data processing system. The approximate transformation computes the LANDSAT coordinates and displays the area on a TV monitor. Positional error of the ground control points displayed to the investigator are designated to the computer by the cursor. This error measurement is used by the computer to derive a set of coefficients for the transformation matrix.

The procedure is then repeated on additional ground control points until the desired geometric accuracy is achieved. This rapid interactive procedure is essential for producing a transformation matirx which provides an accurate correction for the spacecraft data. This correction is then applied during the preparation of all data products.

Resampled Computer File Tapes

The categorized-merged tapes were processed to aggregate the categorization of each scene into a standard categorization code for the entire state. The state was sectioned into rectrangular groups of quadrangles in order to obtain the best categorization and complete coverage of the state.

Resampled computer file tapes were produced for the basic inventory data unit of a 7-1/2 minute quadrangle. The specific data unit size, resolution element size and tape header information were designed to interface with the state's data management system. Each quadrangle (data unit) is preceded by a tape header as described on page 18. The resolution elements obtained by resempling the LANDSAT data are defined by a grid size of 30.48 meters in the east-west direction and 182 lines per quadrangle in the north-south direction (N-S length approx. 75 meters). The elements are north-south oriented on the resampled tapes. It should be noted that many of the quadrangles contain a "primary" or "subordinate" title, which indicates the preferred categorical and geometric data where possibly a "subordinate" quadrangle appears on another tape.

SAMPLE DATA UNIT

DESCRIPTION OF HEADER RECORDS (RECORD 1) FOR RESAMPLED LANDSAT QUAD TAPES

The header record size is 30 EBCDIC characters as follows:

Character	Description
1 - 6	'ERTS-1' or 'ERTS-2'
7 - 14	Date of flight: A blank followed by day of month, numberals, month of year abbreviated to three alpha characters, and year abbreviated to two numerals. Example: '29JUN74'
15 - 30	Constant 'Cb' (b for blank), then Latitude direction (N or S) and magnitude in degrees and minutes followed by '/' and Longitude direction (E or W) and magnitude in degrees and minutes. Example: "C N42-13/W115-35' Meaning: Format center C is Latitude North 42° 13', Longitude West 115° 35'.

DESCRIPTION OF QUAD FILE IDENTIFICATION RECORD 4...(n+2)

The record size is 80 EBCIDIC characters

Character	Description
1 - 2	Quad identification code (Ø Ø if outside state)
3	Blank
4 - 30	Quadrangle Name (or "outside State of Ohio"_
31 - 39	Blank
40 - 49	LANDSAT scene number (ØØØØ-ØØØØ)
50	Blank
51 - 60	Categorization indicator "primary" or "Subordinate" (this word indicates the primary or a subordinate categorization for the particular quadrangle)

Land Use/Cover Categories Identified

Table 2, p. 21 lists the type of land cover categories identified for the entire State of Ohio, and shows the category code number used for each category for the computer tape files.

The categories listed in Table 2 were named to provide a brief title of the land use/cover they include. A summary of some of the characteristics of each category follows.

Urban, Core. Developed areas with high concentration of impermeable surface and no vegetation, such as central business district and high density industrial, commercial and residential areas. This category also includes portions of the Ohio River, indicating that at the time of data acquisition the river was at low flow stage exposing large areas of the river bottom and banks, or that the river was highly turbid (high suspended sediment).

Urban, Residential. Developed areas with medium concentrations of impermeable surface and limited vegetation, including medium density commercial and single and multifamily residential areas.

Urban, Suburban/Agriculture. Developed areas with medium concentrations of impermeable surface and limited vegetation, including low density commercial and low density single and multifamily residential areas. Older houses with large tended grass or brush areas, are included in this category.

Agriculture, Vigorous Growth. No specific ground truth was available for determination of crop types over the State. Since the inventory is more concerned with agriculture vs. non-agriculture delineation, the growing agriculture was divided into only two subgroups. Vigorous growth agriculture includes those crop types with a high chlorophyll content growing in thick density.

Agriculture, Medium-Sparse Growth. This category includes areas where the crop may contain a lower chlorophyll content, or is growing in medium to thin denstiy, or has been recently harvested.

Agriculture, Bare Fields. This indicates cropland areas that have been harvested and/or plowed. It should be noted that both July 1975 and April 1976 LANDSAT data was used in the inventory, and areas which were bare in Arpil 1976 may have experienced vigorous growth in July 1975. The categorization indicates the condition during the LANDSAT scene date.

Agriculture, Pasture. These areas are non-cropland fields or late season grain crops.

Rangeland, Reclaimed Stripmine/Urban. The category was chosen to define reclaimed stripmine areas; the category also appears in the urban areas where the rock-grass area appears similar to the buildings-grass areas in the LANDSAT data. The differentiation may be easily made by noting the geographical (i.e., city-country) location of this category.

Rangeland, Scrub and Brush. This category exists where vegetation has partially regrown in areas previously disturbed by agriculture and/or urban development, or in areas of low soil moisture content.

Rangeland, Herbaceous. This category encompasses lands dominated by naturally occurring grasses. Due to the seasonal period of the LANDSAT data, the category will include naturally occurring grasslands and planted recreation lands.

Rangeland, Grass-tended. Grass that is highly fertilized and watered, including golf courses, cemeteries, parks and/or recreation areas.

Forest, Mixed decidious, including lowland and upland types. Significant stands of conifers were not identified in the ground truth data.

Water, Turbid. Water in rivers, lakes, reservoirs and basins with a high quantity of suspended sediment.

Water, Clear. Water in rivers, lakes and reservoirs with a low amount of suspended sediment or algae content.

Wetland, Non-Forested. Areas dominated by herbaceous vegetation or nonvegetated, including tidal marshes, freshwater meadows, wet prairie and open bogs.

Wetland, Forested. Wetlands dominated by woody vegetation, including seasonally flooded bottomland hardwoods, wooded swamps, and areas around bogs.

Barren, Settling Pond. Areas created for processing and/or waste storage of solidified material.

Barren, Beaches. Smooth sloping accumulations of sand and gravel along shoreline.

Barren, Mines, Quarries and Gravel Pits. Areas where extractive mining activities have significant surface expression. Flooded areas are typically placed in the water category.

Barren, Stripped Bare. Areas where significant strip mining and/or construction has greatly disturbed the landscape.

Barren, Stripped/Urban. These areas were originally identified in the barren categroy, but are also found in the urban area where large concentrations of buildings or concrete or transportation centers look similar in the LANDSAT data. The category can be appropriately defined in the context of the locality where it exists.

Uncategorized. This category includes all pixels that do not fall into the remaining categories.

TABLE 2

CATEGORY NAME AND NUMBER ASSIGNMENT

Urban	01	
Core		011
Residential		012
Suburban/Agriculture		013
Agriculture	02	
Vigorous Growth		021
Medium-Sparse Growth		022
Bare Fields		023
Pasture		024
Rangeland	03	
Reclaimed/Urban		031
Scrub & Brush		032
Herbaceous		033
Grass-tended		034
Forest	04	
Mixed		041
Water	05	
Turbid		051
Clear		052
Wetland	06	
Non-Forested		061
Forested		062
Barren	07	
Settling Pond		071
Beaches		072
Mines, Quarries & Gravel Pits		073
Stripped/Bare		074
Stripped/Urban		075
Uncategorized	00	

Special Processing and Problems

During the training and analysis of the LANDSAT data, two common problems were resolved by special processing techniques. One problem, which occurred throughout the categorization of all the scenes, involved confusion of the urban (residential-suburban) and barren (extractive-bare earth) categories. The problem was resolved by judicious selection of training areas where the classification could be easily determined based on the geographic location of the category. For example, the Barren, Stripped/Urban category was selected for categorization of active strip mining, but also appeared in the central urban areas. The correct categorization (Barren or Urban) is easily identified when one notes whether the category is in an urban area, or in the countryside. For statistical purposes, the boundary of the specific area may be digitized and correctly included in any tabulation of a large area which may encompass both types of land-use.

The second special problem involved agriculture/urban categorization in a specific location centered near Defiance, Ohio. In this case, the problem appeared to be a factor of geology, soils, crop condition and season in the 2190-15410, 31 July 1975 scene. The problem was that urban categories selected with training sets in the Toledo area appeared in the agricultural fields near Defiance. The general shape of this area approximately corresponded to an arrowhead pointed in a southwest direction. Further investigation and analysis indicated that the anomalous urban category was directly related to a flat expanse of moderately dark colored, poorly drained Paulding soils deposited during the last glaciation. This area was apparent

the LANDSAT black and white, band 5 image and local geologic maps. (Refer to "Know Ohio's Soil, 1973).

This problem was resolved by performing the training, analysis and processing twice for the same area. The initial work was done for the correct categorization outside of this particular Defiance area, and a second categorization was undertaken for the agriculture in the specific area.

The data was processed for both categorizations, and two processed merged tapes were produced. Quadrangles for the resampled computer file tapes were specifically selected from one or the other categorization to provide the best classification. Quadrangles from Lyons southward to Malinta and those to the east were resampled from the categorization favoring the Toledo urban area, while those quadrangles to the west and south of N41-30-00, W84-07-30 were chosen from the Defiance agricultural categorization. An additional tape of the anomalous - subordinate quadrangles in the Toledo area was delivered for further analysis by the State. Therefore, this specific problem due to geologic soil deposits was resolved by performing two categorizations and selecting the correct categorization for each particular quadrangle in the vicinity of Defiance, Ohio.

Evaluation of Categorization

Before producing categorized data for each LANDSAT scene covering a protion of the state, a number of tests were applied to evaluate the computer's ability to perform the desired interpretation. The tests included generation of categorization-accuracy tables, and viewing the processed imagery on the

MDAS TV monitor. Selection of training areas, generation of accuracy tables, and evaluation of processing results through use of computer print-outs and the TV monitor were iterative operations, and were performed for each LANDSAT scene.

Ground truth data which remained from the initial training set selection were compared with a category-color coded display of the area on the MDAS monitor. The categorization was verified through the use of the ground truth points, aerial photography and map data at various scales. Finally, the quadrangle file tapes were displayed, examined and compared with ground truth data and maps for a final evaluation.

Table 3 is a categorization accuracy table for scene 2188-15300. It should be read row by row and measures the percent of each training set as it is categorized by the categorical coefficients, against each of the categorical groups. Row 9, for example, indicates that, when the pixels in training set 9 are categorized, 20% of the pixels are categorized into group 2, which is water, and 76% are categorized into group 9, which is also water of apparently similar qualities.

Ground Control Points

For this investigation, approximately 1,000 total ground control points were used to precisely control the LANDSAT data. The RMS error was typically less than two picture elements (pixels) and two scan lines. The ground control points were digitized from 1:24,000 scale maps.

CATEGORIZATION TABLE

REJECTION LEVEL =5.0 STANDARD DEVIATIONS

NOV = A

NUMBER OF GROUPS =33

NUMBER OF BANDS DELETED = 3

ORIGINAL PAGE IS OF POOR QUALITY

TNG SET	PERCENT CATEGORIZED AS GROUP 0	2	3	4	5	6	7	8	9	10	11	14	15	16	18	19	20	21	22	24
2	0.	95.	0.	0.	0.	0.	0.	0.	0.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	98.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	98.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.	92.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.	0.	90.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
9	0.	20.	0.	0.	0.	0.	2.	0.	76.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	2.	0.	0.	0.	0.	0.	0.	0.	98.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	94.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	99.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.	0.	0.	0.	9.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.	9.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
41	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
42	0.	0.	0.	0.	0.	0.	0.	19.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

TNG SET	PERCENT CATEGORIZED AS GROUP 25	26	27	28	29	30	32	34	35	36	37	40	41	42
2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.
6	0.	0.	2.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	10.
9	0.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	6.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
25	98.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.
26	0.	91.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
27	0.	0.	98.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
28	0.	0.	2.	89.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.	0.	0.	97.	3.	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.	0.
37	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	100.	0.	0.
41	0.	0.	0.	0.	0.	2.	0.	0.	0.	2.	0.	0.	96.	0.
42	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.	0.	0.	0.	79.

ORIGINAL PAGE IS OF POOR QUALITY

Table 3. Categorization Table for Scene 2188-15300

CHAPTER II-3

BUILDING THE DATA MANAGEMENT SYSTEM

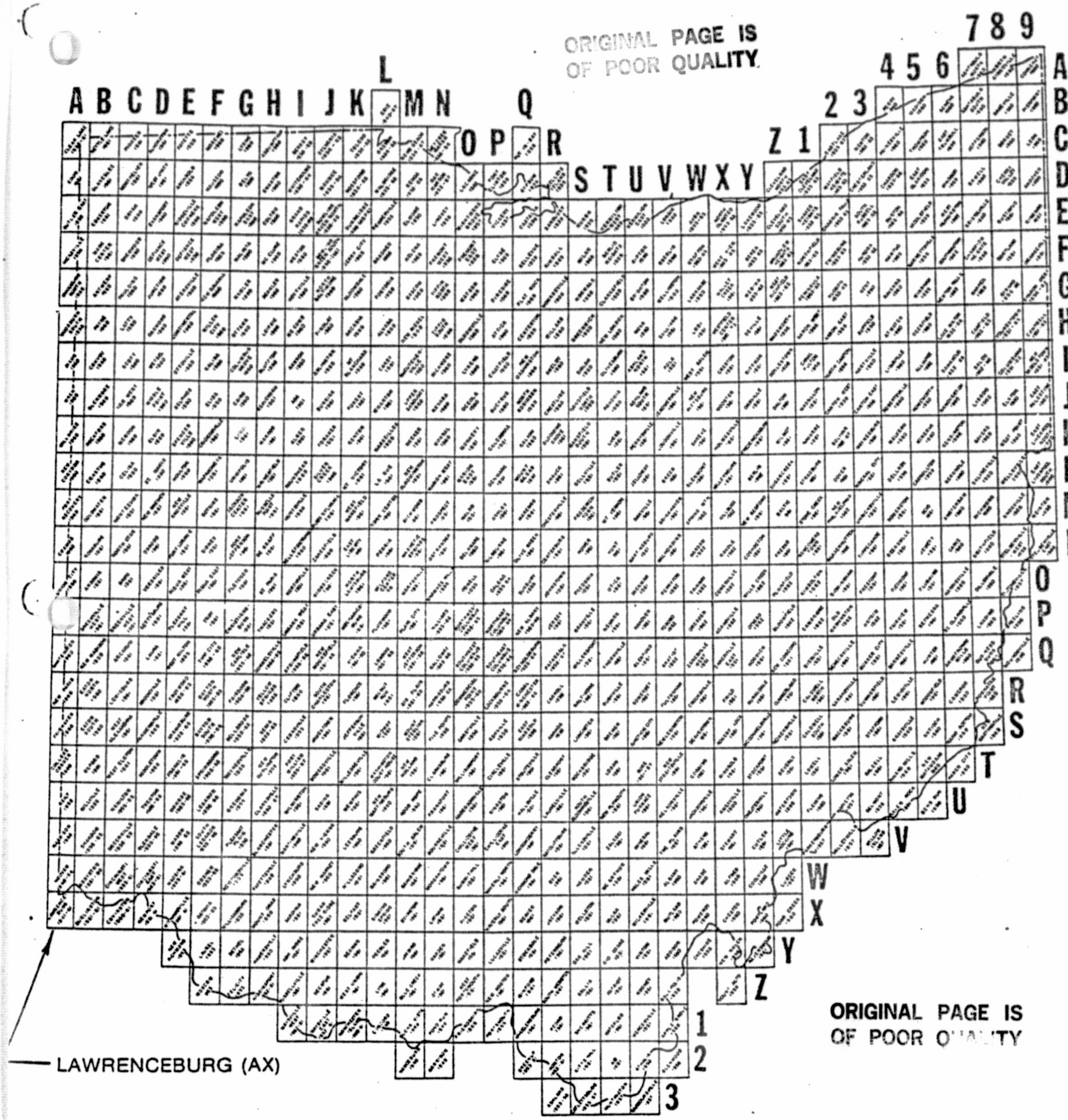
<u>Creation of Digital Political Boundary Files</u>

The initial phase in the development of the Land Use Inventory for the State of Ohio was to convert all counties and townships into the digital format of the OCAP[1] system. The counties and townships could later be masked with the appropriate LANDSAT information to produce tabular summaries and maps of land cover for each political unit. Source maps used for the conversion process included an Ohio county/township map at the scale of 1:500000, and the 788 USGS 7-1/2' quadrangles of Ohio at the scale of 1:24000.

An identification system was developed for referencing and storing each quadrangle as a computer file. A quadrangle index sheet, showing all quadrangles in the state, was coded in the horizontal direction with the letters A - Z and the number 1 - o, beginning in the northwest and continuing to the northeast. The vertical direction was coded with the letters A - Z and the numbers 1 -3, beginning in the northwest and continuing to the southwest (Figure 7). To determine the identification of any quadrangle, one would first read the letter or number corresponding to the column in which

1. OCAP is an acronym for Ohio capability analysis program. It is a computer information and mapping system which consists of various programs used to digitally store and analyze information which is necessary to determine the capability of land to support given functions.

FIGURE 7.
QUADRANGLE IDENTIFICATION SYSTEM



43

the quadrangle is located, then the letter or number corresponding to the row. As an example, Lawrenceburg quadrangle, in the southwest corner of Ohio, would be coded "AX".

Digitizing of political boundaries necessitated the use of consistent and accurate measurements for the horizontal and vertical distances of each quadrangle. Quadrangle measurements were then determined from <u>Cartographic Tables of Topographic Instructions of the United States Geologic Survey</u>.

Eleven Ohio townships were then located on the quadrangles with the exception of Cuyahoga County. The Regional Planning Commission from Cuyahoga County provided 1976 municipality and corporate limits as an alternative to township units.

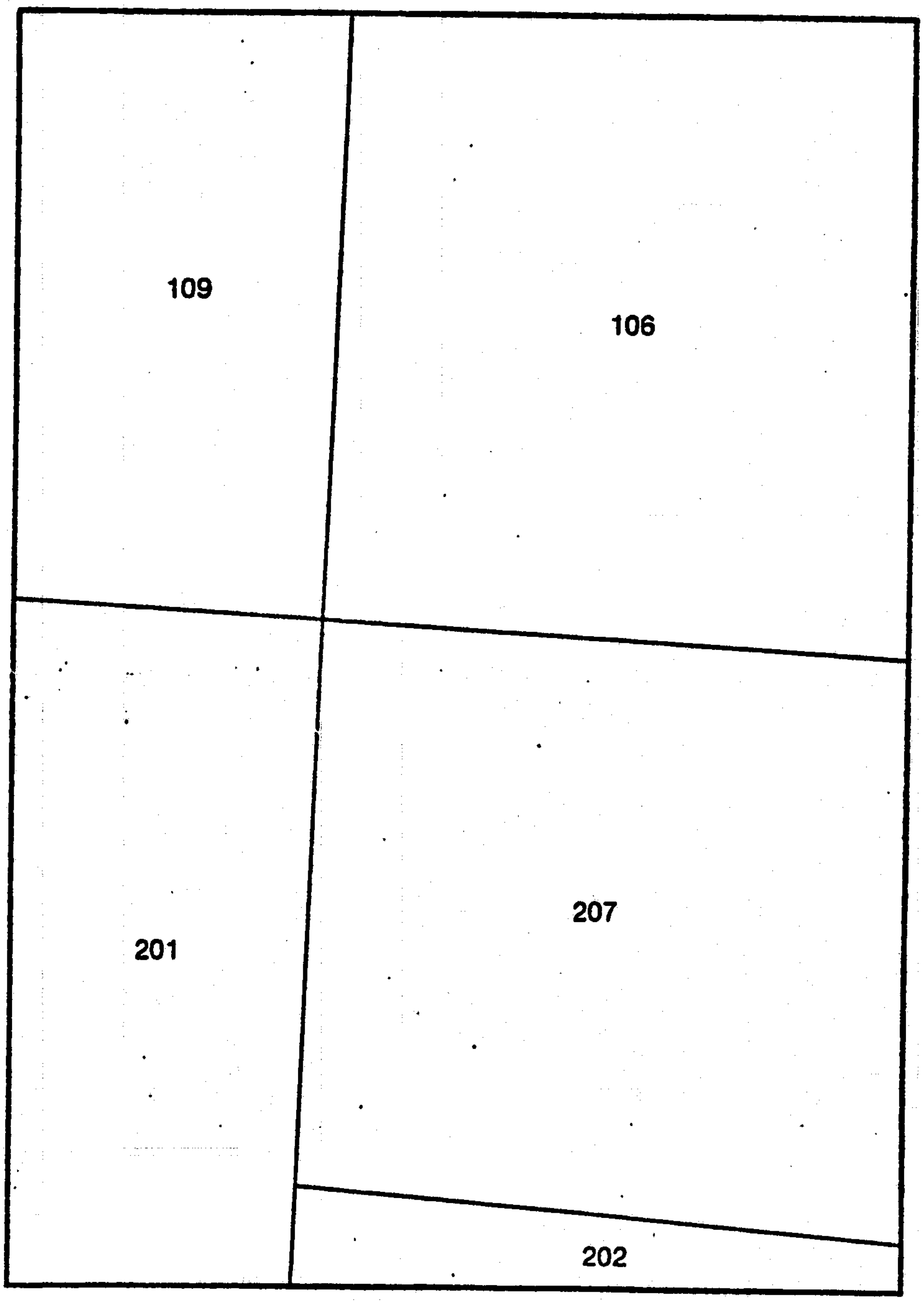
<u>Encoding and Digitizing Political Boundaries</u>

Political boundaries were encoded on the 7-1/2' quadrangles with appropriate county/township identification codes (Figure 8). Each county was assigned a single digit county identification number ranging from 0 to 9 so that no two adjacent counties would have the same number. Each township, in alphabetical sequence within a county, was assigned a two digit number ranging from 01 to nn (Figure 9). An example, Bedford Township in Meigs County has an identification number of 201. The "2" is the county identification and the "01" is the township identification. This numbering system insured that no two political units on a given quadrangle would have an identical code.

FIGURE 8.

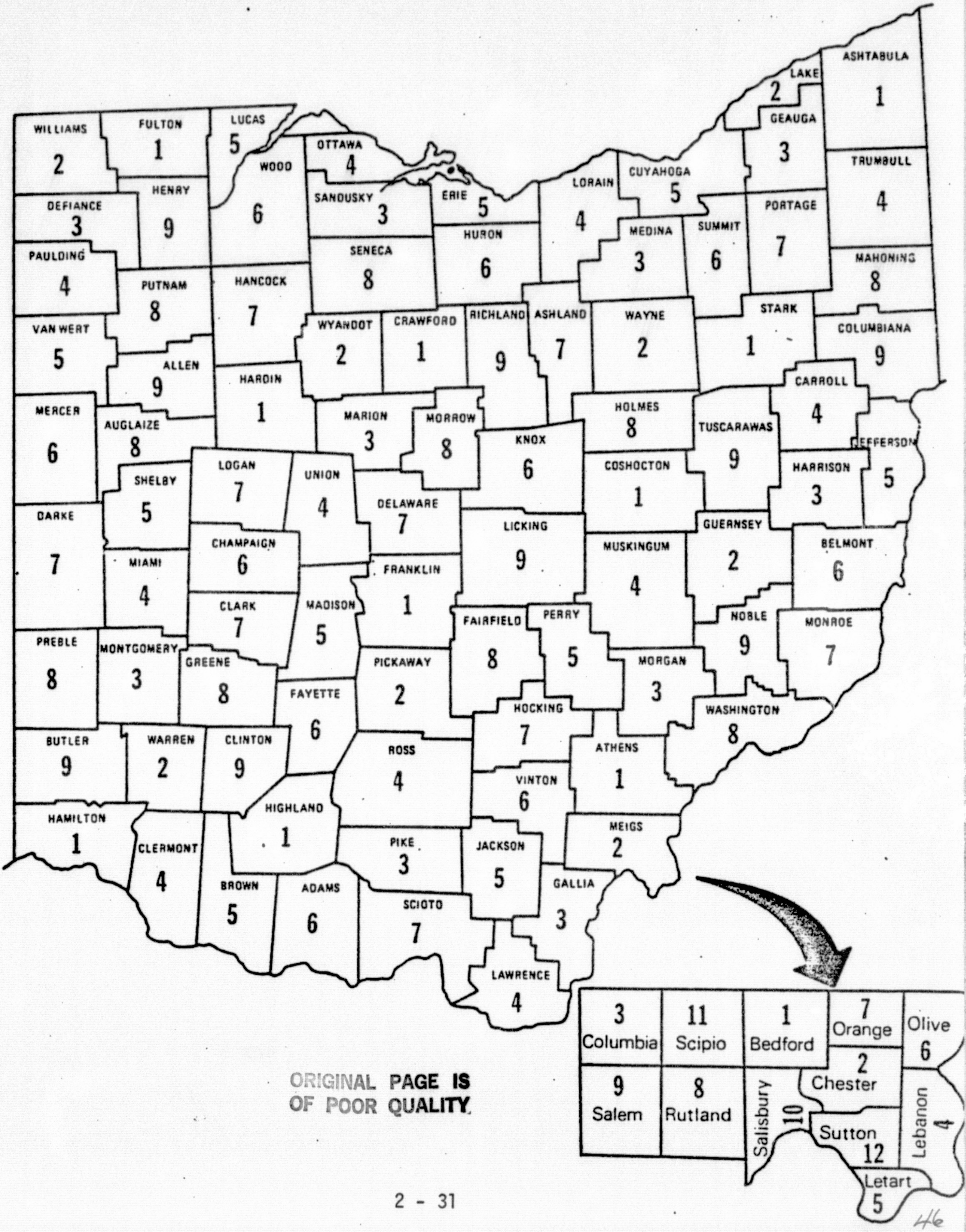
POLITICAL BOUNDARY BASE MAP

ALFRED QUADRANGLE



COUNTY/TOWNSHIP IDENTIFICATION CODE	COUNTY	TOWNSHIP
106	Athens	Carthage
109	Athens	Lodi
201	Meigs	Bedford
202	Meigs	Chester
207	Meigs	Orange

FIGURE 9.
COUNTY/TOWNSHIP IDENTIFICATION MAP



46

Seventy-five percent of the quadrangles were digitized, using a polygon method and twenty-five percent using a row segment method unique to the OCAP system. The polygon method required circumscribing each county/township unit and recording vertices of each. The row segment method required digitizing 182 lines of information in the Y - axis with appropriate county/township codes.

The digitizing method selected was dependent upon the efficiency and accuracy of data conversion. Output form digitizing was a punched card deck representing political boundary locations within each quadrangle.

<u>Processing and Mapping of Political Boundary Data Files</u>

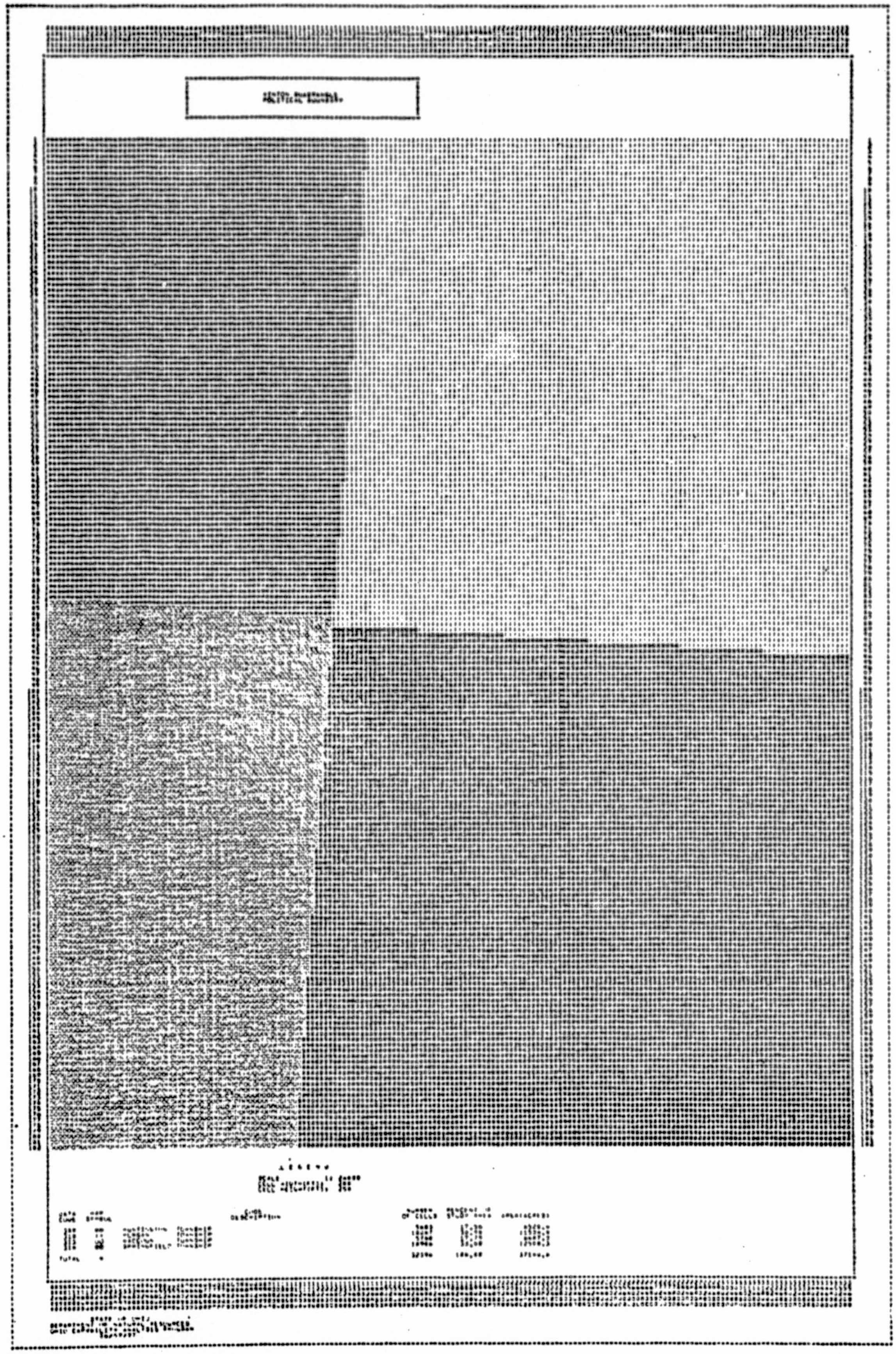
The quadrangles digitized using the polygon method were first processed through the POLYGON program to convert digitized vertices for political boundaries into the standard row segment format of the OCAP system. The quadrangles digitized using the row segment method were processed through the EDIT 2 program. Input for both methods included the punched card deck and program control cards. Output was disk storage of the political boundary data files and a listing of each file.

The output files were then mapped using the MAP program. A line printer map with character dimensions of 200' x 250' (1.15 acres) was produced for each quadrangle (Figure 10). Mapping was necessary to verify the accuracy of the data conversion.

<u>Verification and Editing of the Political Boundary Data Files</u>

A visual edit was performed for each political boundary file. The computer map was compared to its corresponding quadrangle to insure all information

FIGURE 10.
POLITICAL BOUNDARY LINE
PRINTER MAP



48

was converted accurately. Errors were flagged on the computer map and edited using the EDIT 2 program (Figure 11). All political boundary quadrangle files were then permanently stored on computer tape.

Creation of Political Boundary County Files

After all political boundary quadrangle files encompassing a particular county were completed, the individual quadrangles were merged into a county area file using the MERGE program (Figure 12). The county area file contained information not only for the county of particular interest, but also information for portions of counties adjacent to it. The BOUNDARY program was used to separate the county of interest from the county area file.

The political boundary county file was then mapped, verified for data accuracy, and copied to permanent storage on computer tape.

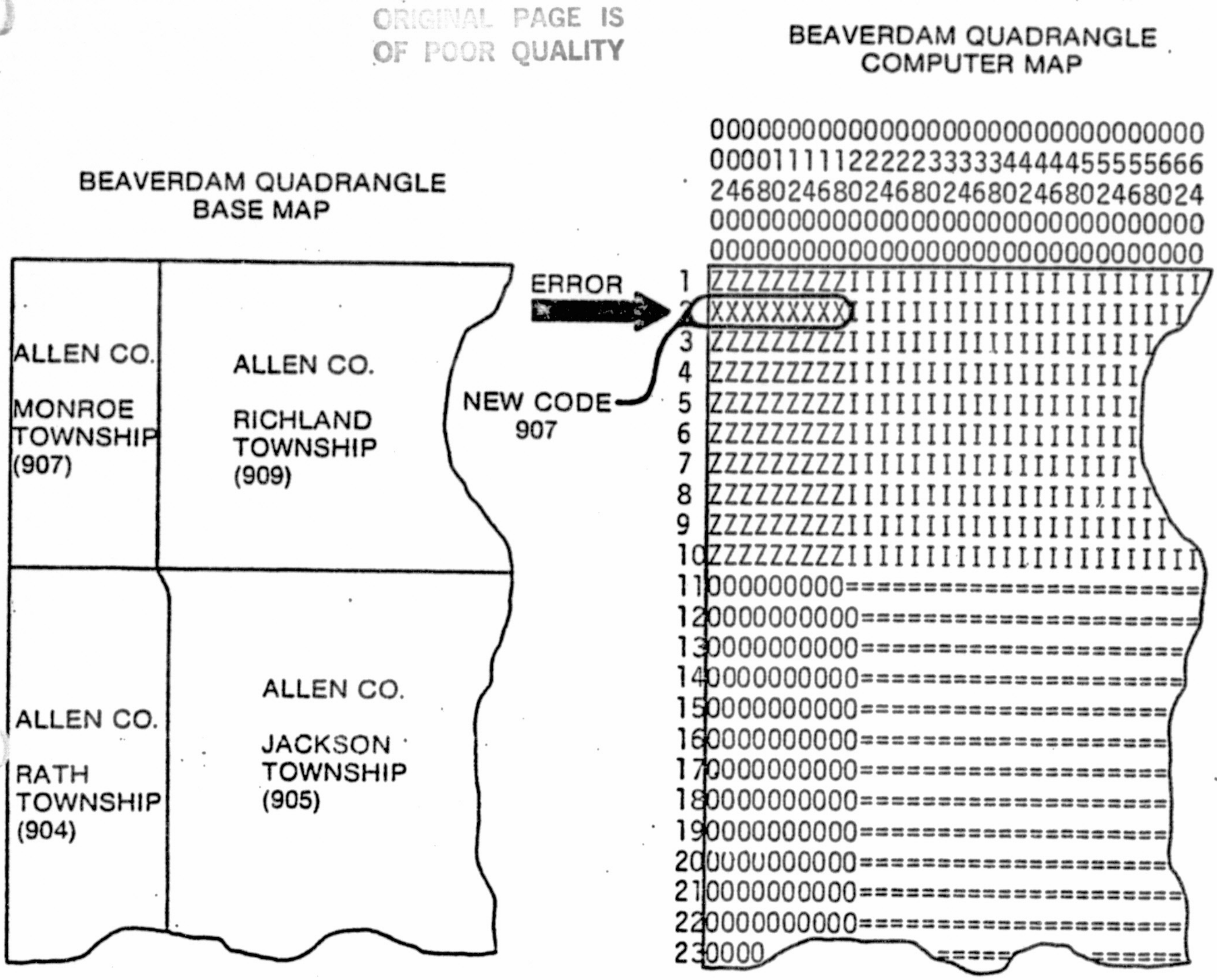
Conversion of Bendix Land Cover Files

The next major phase in developing the Land Use Inventory for the State of Ohio was to create LANDSAT land cover files, which were the basic input into the inventory. LANDSAT data was developed from 11 LANDSAT scenes acquired in 1975-76 by the Aerospace Division of Bendix Corporation[1]. The data was forwarded to the Ohio Department of Natural Resources for reformating to the OCAP system. The reformated data could then be used with the political boundary data to produce tabular summaries and maps for townships

1. For a detailed discussion, see Bendix Report BSR 4255.

FIGURE 11.
VISUAL EDIT

ORIGINAL PAGE IS
OF POOR QUALITY



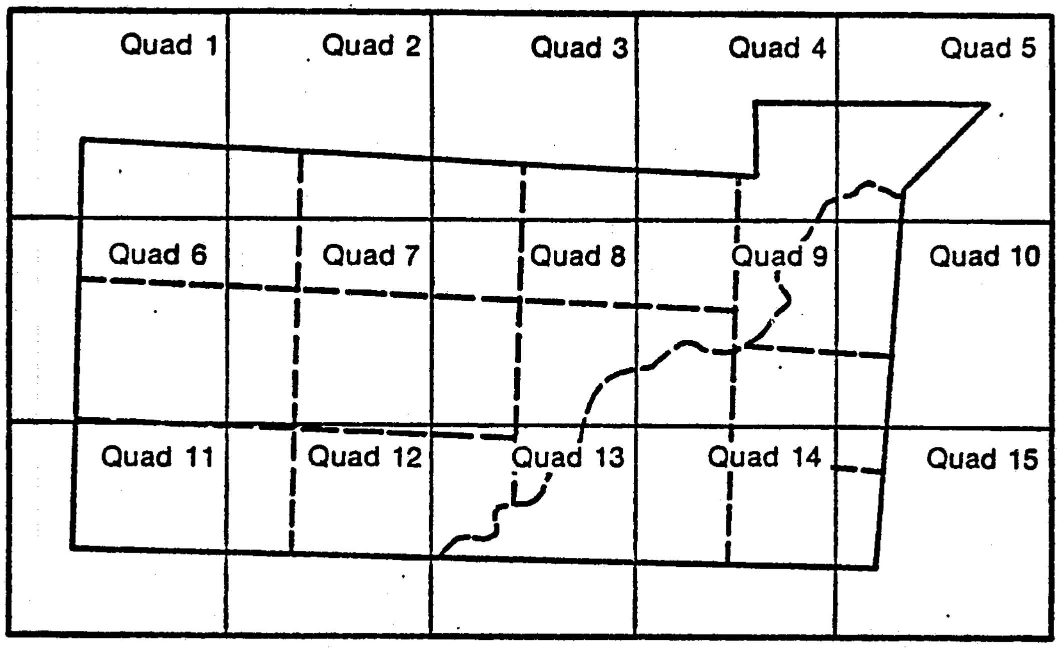
DATA CODE	MAP SYMBOL	CODE DESCRIPTION	
904	00	ALLEN	RATH
905	==	ALLEN	JACKSON
907	ZZ	ALLEN	MONROE
909	II	ALLEN	RICHLAND
910	XX	ALLEN	SHAWNEE

50

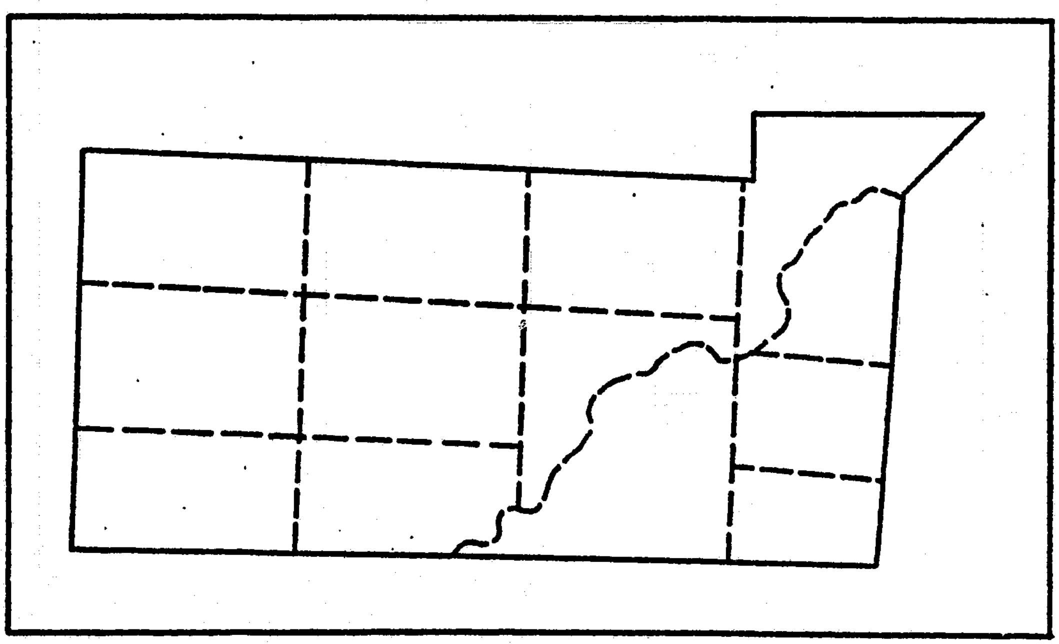
FIGURE 12.

POLITICAL BOUNDARY COUNTY AREA AND COUNTY FILES

POLITICAL BOUNDARY COUNTY AREA FILE — Butler County



POLITICAL BOUNDARY COUNTY FILE — Butler County



Dotted lines denote township boundaries

and counties in Ohio. Summary information was stored in the MARK IV information management system which will be discussed in Section III.

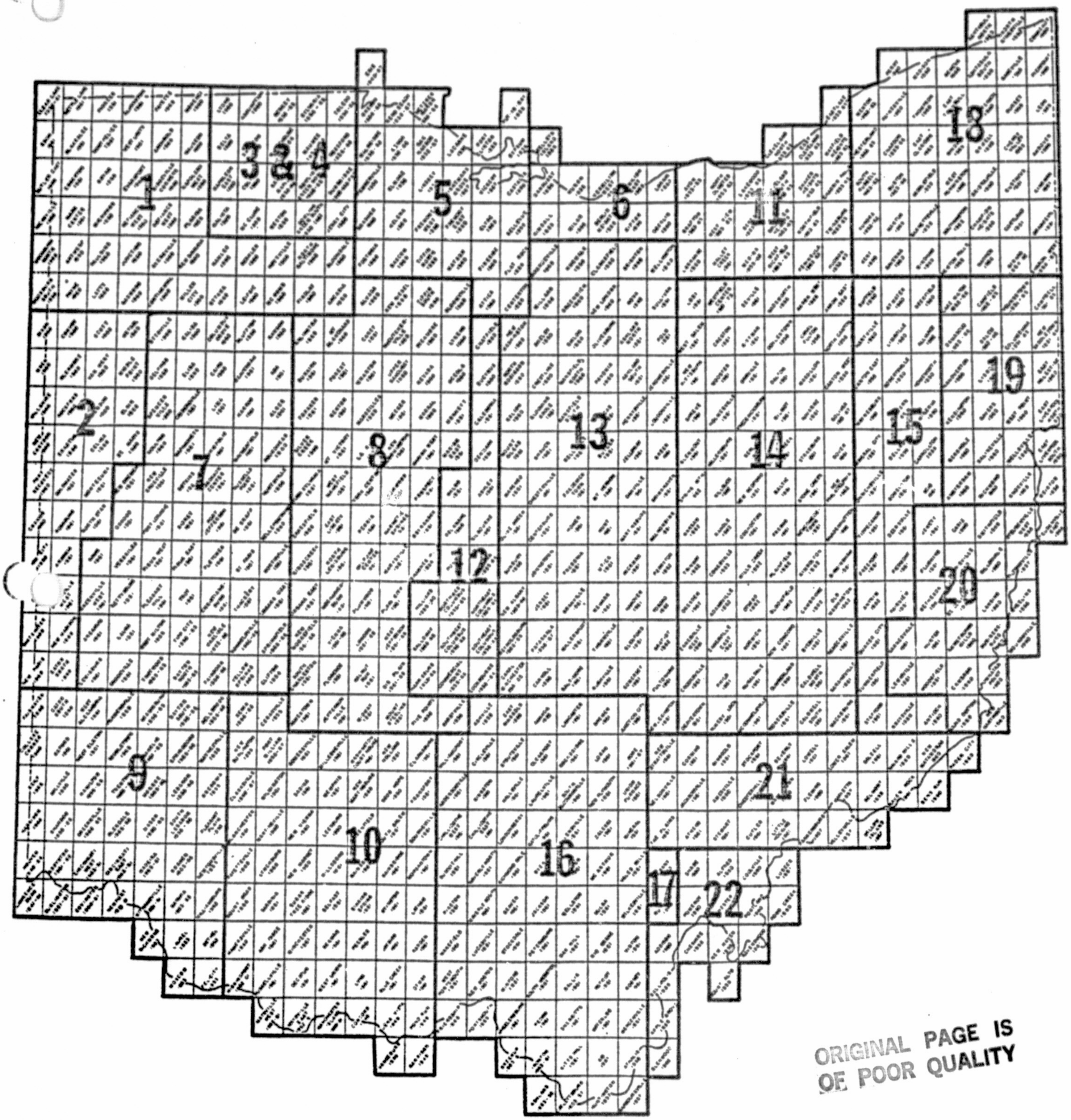
Bendix produced LANDSAT data files for all 7-1/2' quadrangles in the State. Each file was stored on computer tape with the number of files per tape ranging from 2 to 75 (Figure 13). A number of quadrangles were located on two separate tapes as primary and subordinate files. The primary files were used for all subsequent OCAP processing. The data file consisted of descriptions of each quadrangle file and digital data codes representing land cover categories. The categories used in the inventory included 7 level I and 22 level II categories, with an additional undefined category. The level I and level II categories with their corresponding codes were listed in Table 2 with a discussion of categories, but are repeated here for convenience in Table 4.

Format Conversion of Bendix Files to OCAP Files

A computer program called CVTOCAP was written to convert Bendix LANDSAT files into the OCAP format since the Bendix format could not be directly used in OCAP processing. The main purpose of the program was to reformat LANDSAT data from a grid format to the row segment format of OCAP. The program provided a description of each quadrangle file, including scene number, primary or subordinate, date, geographical coordinates, and header characteristics of the output OCAP file (Table 5). The program also had the flexibility of providing either level I or level II categories or aggregating categories upon user specification.

Initial conversion was completed for 105 sample quadrangle files indicated in Figure 14. The sample areas were mapped in a line printer and compared

FIGURE 13.
LANDSAT QUAD FILE LOCATION ON TAPES



1, 2, 3 .... Indicate Tape Number

——— Indicates Tape Boundaries

TABLE 4.

LAND USE/LAND COVER CATEGORIES AND CODES

Categories		Codes	
Level I	Level II		
Urban		01	
	Core		011
	Residential		012
	Suburban/Agriculture		013
Agriculture		02	
	Vigorous Growth		021
	Medium-Sparse Growth		022
	Bare Fields		023
	Pasture		024
Rangeland		03	
	Reclaimed/Urban		031
	Scrub & Brush		032
	Herbaceous		033
	Grass-tended		034
Forest		04	
	Mixed		041
Water		05	
	Turbid		051
	Clear		052
Wetland		06	
	Non-Forested		061
	Forested		062
Barren		07	
	Settling Pond		071
	Beaches		072
	Mines, Quarries & Gravel Pits		073
	Stripped/Bare		074
	Stripped/Urban		075
Uncategorized		00	

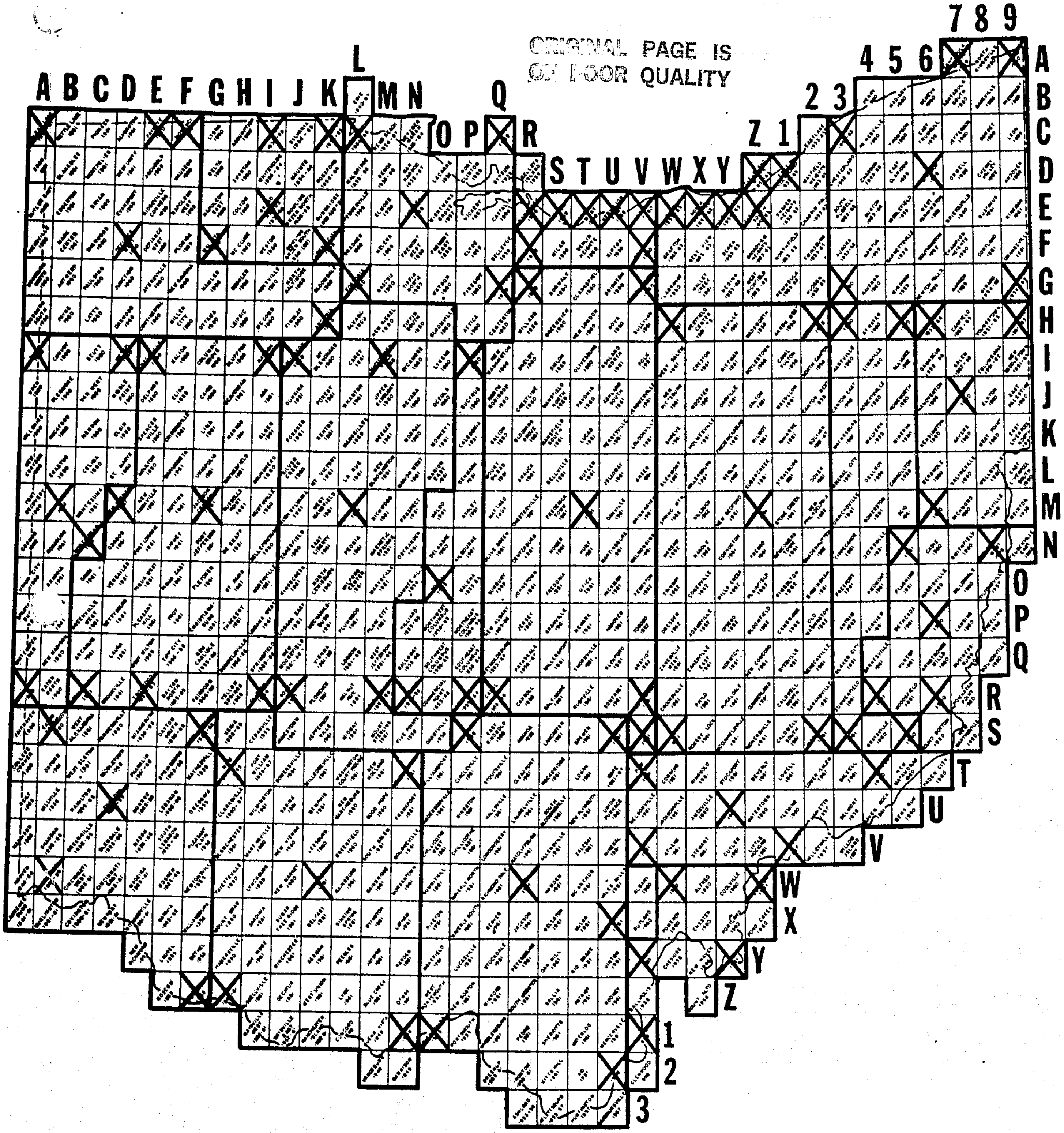
TABLE 5.

Output File Description of Conversion Program

```
**** BENDIX RESAMPLED DATA TO OCAP CONVERSION ****

            DATE (MM/DD/YY):    11/26/76
            TIME (HH:MM:SS):    19:54:28

  BENDIX HEADER DESCRIPTION

  ERTS FLIGHT:                   ERTS-2
  FLIGHT DATE:                   29JUL75
  SCENE CENTER:                  C N40-25/W082-04
  EAST SAMPLING INTERVAL:          30.4800
  NORTH SAMPLING INTERVAL:          0.0000

  CONTROL SPECIFICATION FROM SYSIN:

  QUAD IDENT:                    OK GALION
  VARIABLE IDENT:                LANDSA  LANDCOVER
  QUAD NUMBER OF INPUT:            5
  OUTPUT FILE DDNAME:            OUT01
  RIGHT DISTANCE (FIRST):        3463
  RIGHT DISTANCE (LAST):         3470
  CATEGORY TYPE:                 A
  ZERO CODE REPLACEMENT:           80

  LAT-LONG OF N.W. CORNER:          N 40 45.0    W  82 52.5
  LAT-LONG OF S.E. CORNER:          N 40 37.5    W  82 45.0
  # OF OUTPUT ELEMENTS:               347
  # OF OUTPUT LINES:                  182
  QUAD IDENT FROM INPUT:       OK GALION                                    2188-15300

  OCAP FILE DESCRIPTION

                           FILE NAME:   OK GALION
                       VARIABLE NAME:   LANDSA   LANDCOVER
                        DATE CREATED:   761126
                        DATE UPDATED:   000000
                      MAX PAIR COUNT:     105
                     NO. OF VARIABLES:      1
                        STARTING ROW:       1
                          ENDING ROW:     182
                               SCALE:   1: 24000
                       DISTANCE UNIT:   10. FEET
                        LARGEST CODE:      80
                    LARGEST DISTANCE:    3470

  OUTPUT FILE CREATED
```

ORIGINAL PAGE IS OF POOR QUALITY

FIGURE 14.
SAMPLE QUADRANGLES MAPPED FOR VISUAL COMPARISON



Indicates Quads Converted and Mapped For Visual Comparison

Indicates Tape Boundaries

.56

for general geometric and classification accuracy with USGS 7-1/2' quadrangle maps. The comparison indicated that tape 11 and 19 could not be used, either because of poor classification (Tape 11) or missing files (Tape 19). The poor classification of Tape 11 was probably the result of choosing a poor LANDSAT scene. It was also noted that most quads had to be shifted somewhat in the X and Y directions, in order to be aligned correctly with their corresponding line printer maps. The files on the remaining tapes appeared acceptable, and were converted into the OCAP format, using the CVTOCAP program and mapped on a line printer (Figure 15). The files were then permanently stored on computer tape for subsequent processing.

Creation of LANDSAT County Area Files

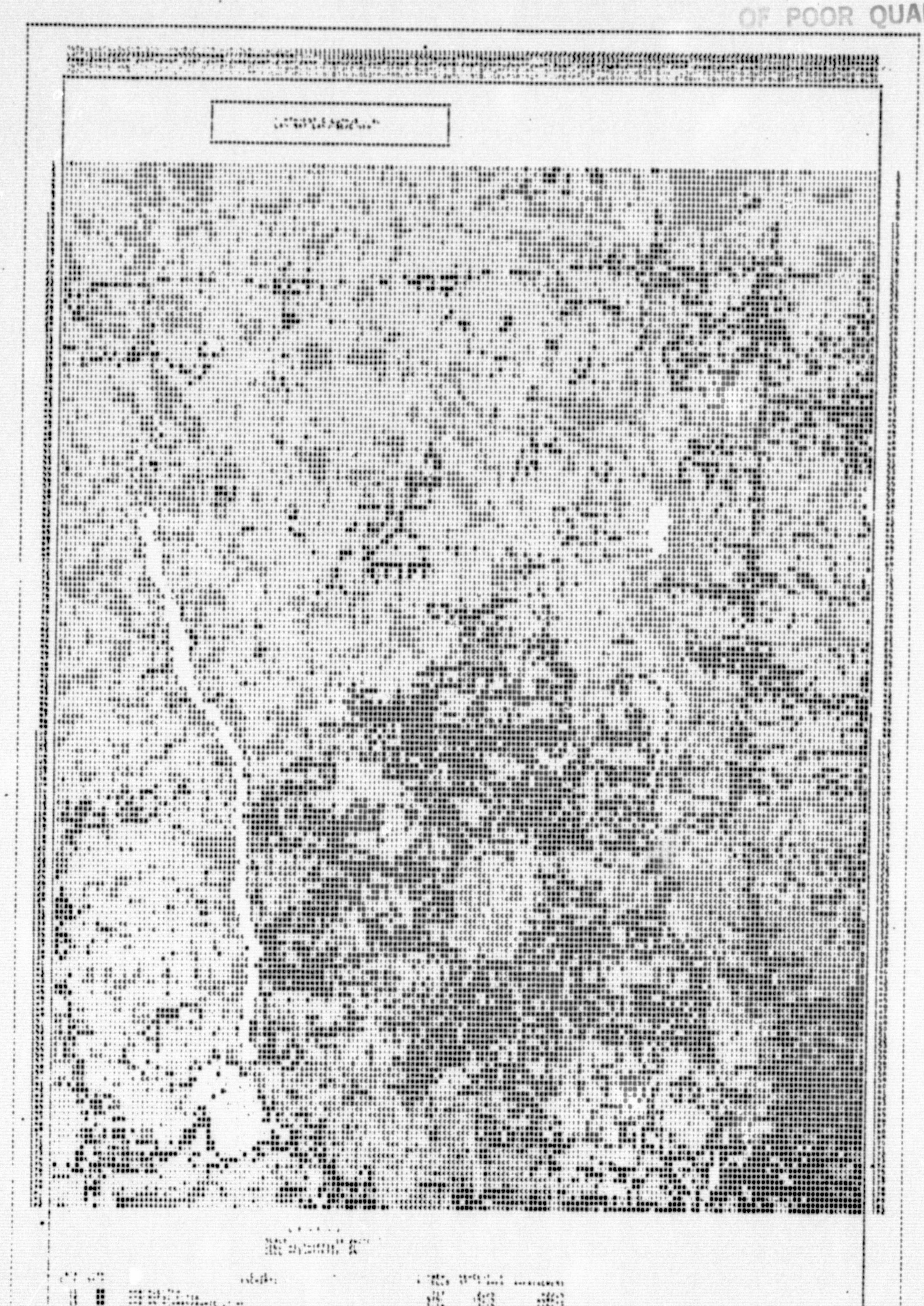
Upon completion of the LANDSAT conversion, the LANDSAT quadrangles encompassing a particular county were merged into a LANDSAT county area file. The merge process was identical to the merge process for political boundaries with one exception. It was not required to create county files since the summaries could be produced using the political boundary county file and LANDSAT county area file.

The LANDSAT county area files were copied and permanently stored on computer tape.

Creation of Statistical Data

The final phase of the Land Use Inventory for the State of Ohio was to develop tabular summaries of land cover for all townships and counties

FIGURE 15.
LANDSAT LAND COVER MAP



by acreage and percentage, and to develop a file management system to manipulate the data. This phase required the use of all political boundary county files and LANDSAT county area files, the OGRE program from the OCAP system, and the MARK IV information management system.

OGRE Program

The OGRE program was used to cross tabulate each political boundary file with its corresponding LANDSAT file. Summaries of acreage and percentage were produced for each township and county (Table 6). The output information was saved and used as input to the MARK IV system.

MARK IV

The MARK IV File Management System, a software product of Informatics, Inc., provides an efficient and flexible means of manipulating date files, and includes such capabilities as automatic file maintenance, retrieval of specified data, computation, and report preparation.

A file structure for the land cover statistics was defined to MARK IV. (Figure 16). This definition describes the logical organization of the different data items along with their type, length and location in the file.

The statistics from the OGRE program were converted to MARK IV defined transactions, which were used to generate the data file. The county and township names were added later through different transactions.

Procedures for extracting, summarizing and formatting the data into different reports were written and stored in the MARK IV system. A user's manual will describe the various reports, and how to obtain them.

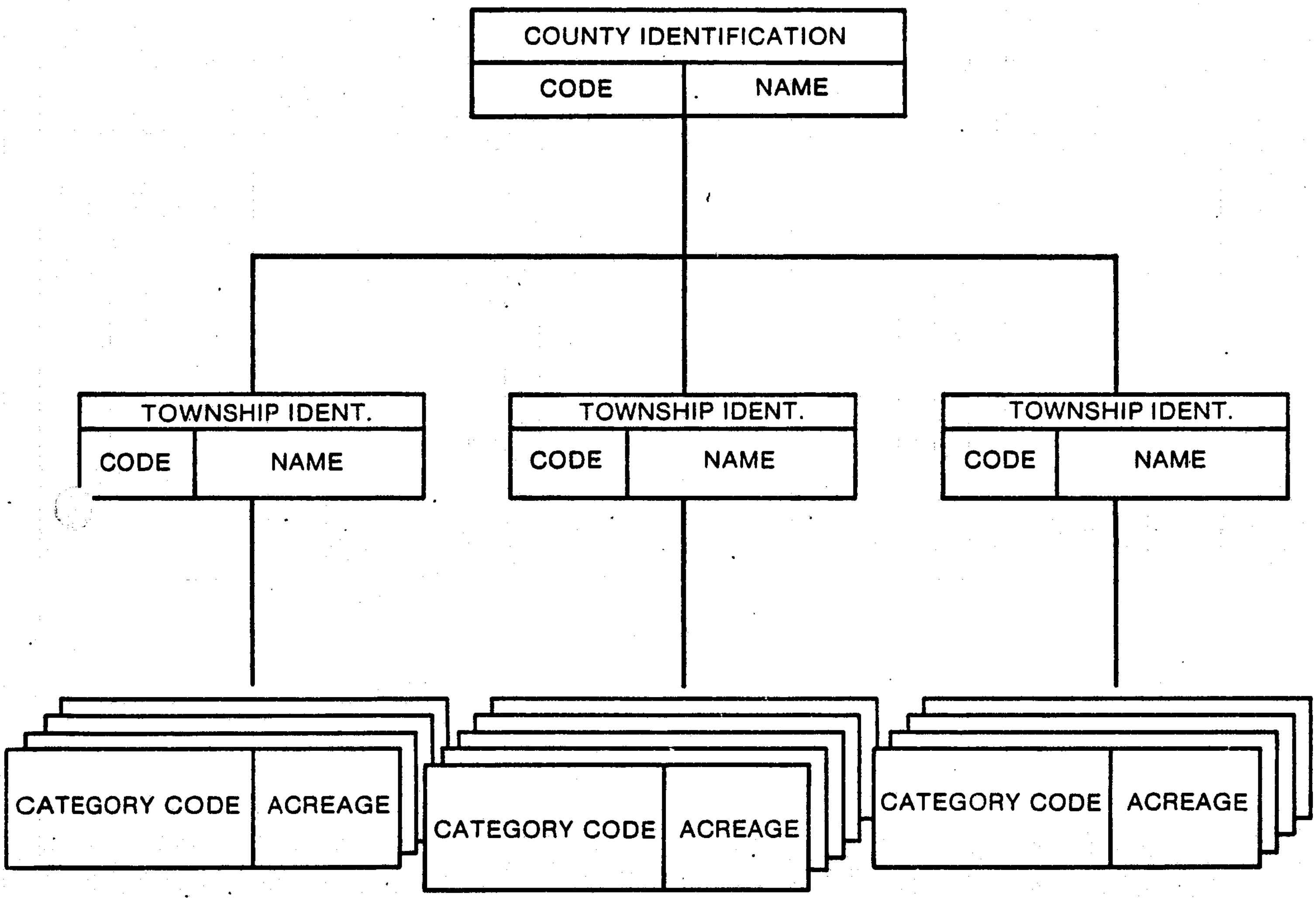
TABLE 6.

Ogre Program Output - Land Cover Summary Form
Washington County

ACRES	PERCENT	WASHINGTON CO LANDSAT LANDCOVER		WASHINGTON CO POLITICAL BOU	
1005,14	5,01	URBAN	RESIDENTIAL/RANGE	WASHINGTON	ADAMS
087,18	20,37	AGRICULTURE	THICK VEGETATION		
155,59	0,78	AGRICULTURE	THIN VEGETATION		
1504,65	7,50	AGRICULTURE	BARE SOIL		
68,47	0,34	RANGELAND	RECLAIMED/URBAN		
222,05	1,11	RANGELAND	SCRUBLAND		
93,09	0,46	RANGELAND	MEADOWS		
2488,52	62,23	FORREST	MIXED		
170,51	0,85	WATER	TURBID		
255,85	1,27	BARREN	SAND		
15,44	0,08	UNIDENTIFIED			
0067,48	100,00	TOTAL			
684,06	3,37	URBAN	RESIDENTIAL/RANGE	WASHINGTON	BARLOW
5846,88	28,78	AGRICULTURE	THICK VEGETATION		
402,61	1,98	AGRICULTURE	THIN VEGETATION		
2087,87	10,28	AGRICULTURE	BARE SOIL		
92.52	0,45	RANGELAND	RECLAIMED/URBAN		
280,76	1,38	RANGELAND	SCRUBLAND		
167,13	0,82	RANGELAND	MEADOWS		
717,69	52,76	FORREST	MIXED		
16,01	0,08	BARREN	SAND		
19,60	0,10	UNIDENTIFIED			
314,90	100,00	TOTAL			
805,96	4,56	URBAN	RESIDENTIAL/RANGE	WASHINGTON	BELPRE
434[illegible],54	24,54	AGRICULTURE	THICK VEGETATION		
23[illegible],46	1,34	AGRICULTURE	THIN VEGETATION		
1031,11	5,83	AGRICULTURE	BARE SOIL		
162,99	0,92	RANGELAND	RECLAIMED/URBAN		
332,07	1,88	RANGELAND	SCRUBLAND		
124,83	0,71	RANGELAND	MEADOWS		
0445,42	59,04	FORREST	MIXED		
2,98	0,02	WATER	TURBID		
182,68	1,03	BARREN	SAND		
26,86	0,15	UNIDENTIFIED			
7692,88	100,00	TOTAL			
667,64	2,97	URBAN	RESIDENTIAL/RANGE	WASHINGTON	DECATUR
2824,78	12,55	AGRICULTURE	THICK VEGETATION		
157,71	0,70	AGRICULTURE	THIN VEGETATION		
1246,16	5,55	AGRICULTURE	BARE SOIL		
19,92	0,09	RANGELAND	RECLAIMED/URBAN		
116,68	0,52	RANGELAND	SCRUBLAND		
51,65	0,23	RANGELAND	MEADOWS		
7384,19	77,30	FORREST	MIXED		
15,61	0,07	BARREN	SAND		
2,30	0,01	UNIDENTIFIED			
2458,62	100,00	TOTAL			
527,15	3,50	URBAN	RESIDENTIAL/RANGE	WASHINGTON	DUNHAM
2877,81	19,11	AGRICULTURE	THICK VEGETATION		
140,04	0,93	AGRICULTURE	THIN VEGETATION		
1117,65	7,42	AGRICULTURE	BARE SOIL		
[illegible],37	0,25	RANGELAND	RECLAIMED/URBAN		
1[illegible],92	0,84	RANGELAND	SCRUBLAND		
10,90	0,07	RANGELAND	MEADOWS		
0065,88	66,85	FORREST	MIXED		
63,13	0,42	WATER	TURBID		
52,23	0,35	BARREN	SAND		
38,45	0,26	UNIDENTIFIED			
5058,52	100,00	TOTAL			

60

FIGURE 16.
LANDSAT STATISTICS FILE:
LOGICAL RECORD FORMAT



61

CHAPTER II-4

VERIFICATION AND EVALUATION OF INVENTORY

Upon completion of the Land Use Inventory, a verification program was undertaken to determine the accuracy of categorization. Two independent efforts are reported here. First reported is that of the State, and the second is an effort by an RPDO (Regional Planning and Development Organization). The RPDO effort was funded by a HUD 701 grant.

Verification System Used by State

Ninety-four quadrangles were chosen on the basis of total or partial aerial photographic coverage within two years of the date of the LANDSAT imagery. They were also chosen so that the percentage of quads verified in each scene was approximately equal to the percentage of quads verified for the entire state (12%). The quads chosen for verification are indicated in Figure 17, and the percentage per scene in Table 7.

A quad-size mylar grid was prepared to use in determining 10 random points to be sampled from each map. The grid was comprised of 100 cells each with a dot at its center.

Numbers from one to ten were randomly selected for the X & Y axes of the grid to determine which 10 points would be used. The coordinates were recorded on the "LANDSAT Verificaiton Form" (Figure 18). The procedure was repeated for each of the selected 94 quads.

Each quad was placed over the mylar grid on a light table, and the rectangle indicated by the coordinates on the verification form was located, and the dot in the center was transferred to the quadrangle.

FIGURE 17.

QUADRANGLES CHOSEN FOR VERIFICATION

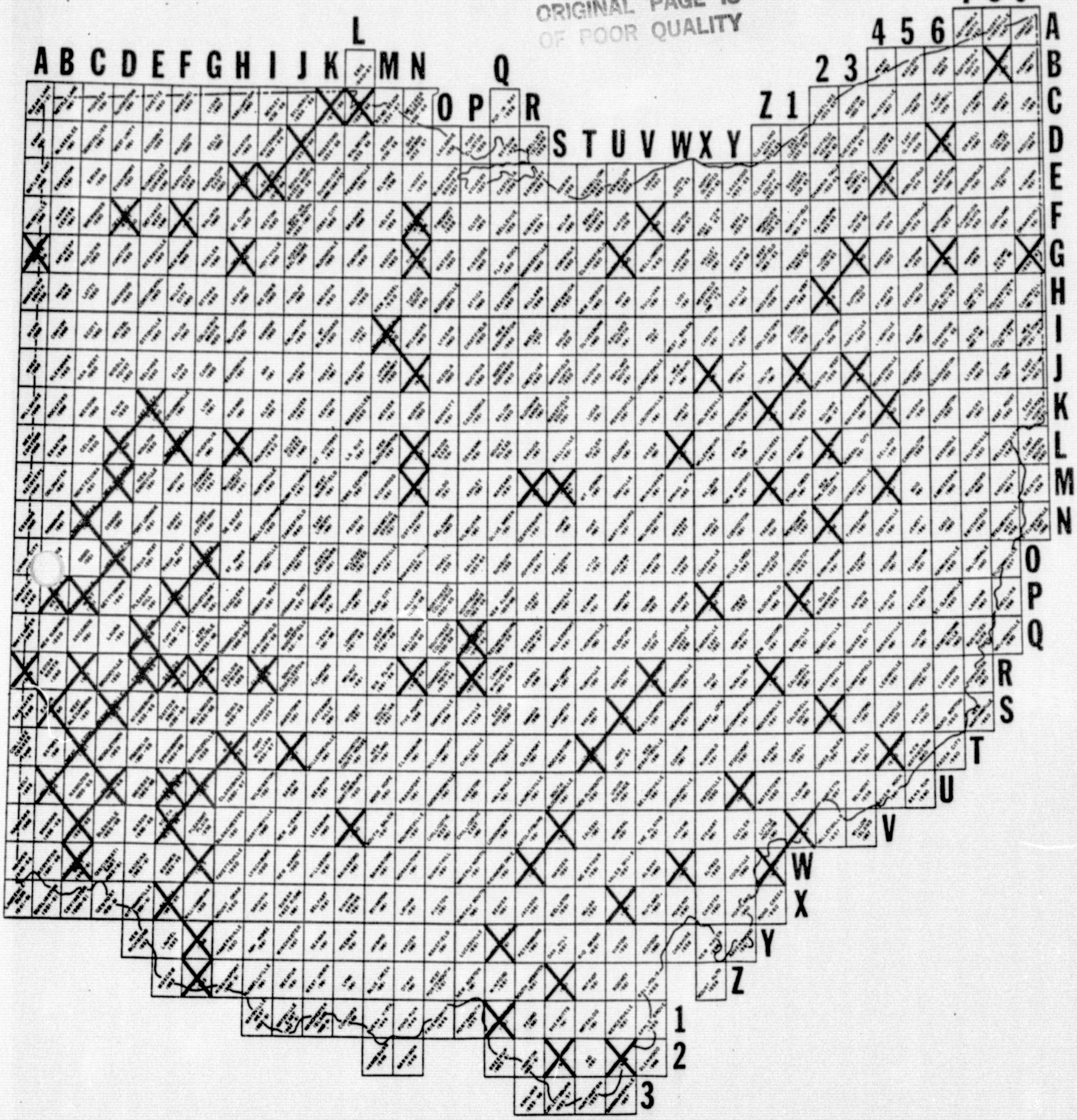


TABLE 7

Summary of Quads Verified Per Scene

SCENE NUMBER	TOTAL IN SCENE	QUADS CHOSEN FOR VERIFICATION	PERCENT OF TOTAL IN SCENE
2190-15410	66	8	12
2189-15352	42	4	10
2439-15195	46	6	13
2439-15204	45	5	11
2440-15262	73	10	14
2441-15320	106	17	16
2442-15372	30	4	13
2189-15355	121	18	15
2188-15300	191	22	12
2439-15201[1]	47	--	--
2278-15283[1]	24	--	--

1. Scenes 2278-15283 and 2439-15201 were contained, either in whole or part, on Tapes 11 and 19 which as previously discussed were not used because of bad or missing data.

FIGURE 18.
OHIO LAND USE INVENTORY
VERIFICATION FORM

Tape 12

SCENE *2189-15355*

SCENE DATE *July 30, 1975*

QUAD NAME *Nevada* CODE *NJ* INTERPRETER *Groves & Weber* DATE *Aptil 13, 1977*

SAMPLE	COORDINATES X	COORDINATES Y	LANDSAT ID	GROUND TRUTH ID	COMMENTS	CORRECTNESS OF LANDSAT ID: YES	CORRECTNESS OF LANDSAT ID: NO
1	1	4	34	23	bare soil/thin veg		X
2	2	2	41	41	all forest	X	
3	2	3	22	22	agri/forest/water	X	
4	4	1	21	22	agri	X	
5	3	1	41	41	mostly all agri/a little forest	X	
6	9	2	12	22	agri		X
7	2	7	22	22	agri	X	
8	10	1	22	22	all agri	X	
9	9	1	41	41	scrub/agri/forest	X	
10	6	2	22	22	agri	X	

TOTAL CORRECT *8*

TOTAL INCORRECT *2*

SOURCE OF GROUND TRUTH:
IF THE SOURCE IS PHOTOGRAPHY, INDICATE IN ORDER THE FOLLOWING DATA

SOURCE	TAKING AGENCY	FILM TYPE	FLIGHT NO.	DATE	FRAMES
1	ODNR	B&W	752090202	7-28-75	34
2					31
3					32
4					25
5					26
6					9
7					13
8					7
9					7
10					014

To make certain that the categorization was being verified, and not the accuracy of aligning the quadrangle map and LANDSAT map, three people independently aligned ten maps and recorded their points of alignment. The maximum displacement of the points of alignment became the radius of an are surrounding each point.

Each sample point and its corresponding area of displacement was located on aerial photography, and the land uses within that area were determined. If the LANDSAT land use matched any of these land uses, it was considered correct, and indicated on the verification form.

Results of State Verification

The following is a discussion of the verification results by category:

URBAN

Urban areas are difficult to identify when the computer is classifying the LANDSAT data. The computer constantly compares the data to the training sets mentioned above, and faithfully labels land cover within an urban area as the land cover which it was trained to identify: agriculture, forest, rangeland, etc. As seen from the definition of the training sets used in the urban areas, an attempt was made to pick out training areas in the central business and industrial (Core), Residential and Suburban/Agriculture areas with the idea that each of these areas would have a unique spectral response just as Forests, Barren, and the others. By looking at Table 8, we find category 11 (Urban, Core), was indeed identifiable as a separate land cover, as - to a lesser extent - was category 12 (Urban, Residential). However, some urban areas and some agricultural areas are

66

TABLE 8.

LAND USE/LAND COVER CATEGORIES AND CODES *

CATEGORIES			CODES
LEVEL 1 **	LEVEL 11 **		
Urban		01	
	Core		011
	Residential		012
	Suburgan/Agriculture		013
Agriculture		02	
	Vigorous Growth		021
	Medium-Sparse Growth		022
	Bare Fields		023
	Pasture		024
Rangeland		03	
	Reclaimed/Urban		031
	Scrub & Brush		032
	Herbaceous		033
	Grass-tended		034
Forest		04	
	Mixed		041
Water		05	
	Turbid		051
	Clear		052
Wetland		06	
	Non-Forested		061
	Forested		062
Barren		07	
	Settling Pond		071
	Beaches		072
	Mines, Quarries & Gravel Pits		073
	Stripped/Bare		074
	Stripped/Urban		075
Unidentified			

* See definitions Appendix I

** Level I categories are very general
Level II categories are subdivisions of
Level I categories and are more specific.

TABLE 9

DISTRIBUTION OF INCORRECT CLASSIFICATIONS

LAND USE/COVER	% INCORRECT	URBAN	AGRICULTURE	RANGELAND	FOREST	WATER	WETLAND	BARREN	UNCATEGORIZED
1. Urban									
11 Core	6		100						
12 Residential	16		75			25			
13 Suburban/Agriculture	61		52	13		35			
2. Agriculture									
21 Vigorous Growth	11			29	57			14	
22 Medium-Sparse Growth	16	30		45	25				
23 Bare Fields	18			50	50				
24 Pasture	13			100					
3 Rangeland									
31 Reclaimed/Urban	38	22	67		11				
32 Scrub & Brush	32	22	72		6				
33 Herbaceous	33		100						
34 Grass-tended	69	8	88					4	
4. Forest									
41 Mixed	5		91	9					
5. Water	0								
6. Wetland	100		100						
7. Barren									
73 Mines, Quarries & Pits	0								
74 Stripped/Bare	100	50	50						
75 Stripped/Urban	13		100						
Unidentified									

NOTE: The % incorrect column indicates the percentage of points that were misclassified for the indicated Level II land cover. The next seven columns indicate the percentage of each category which contributed to the incorrect classifications, e.g., of the points identified as Grass-Tended Rangeland, 69% were not. Of that 69%, 8% of the points were actually Urban, 88% were Agriculture and the remaining 47% were Barren.

not identifiable as separate categories, and are combined to make category 13 (Urban, Suburban/Agriculture).

The important question, therefore, is whether the Urban category can be used with any accuracy. Utilization of the Urban category depends upon the specific purpose of use. LANDSAT is not the answer for determining municipal limits. LANDSAT will, however, give information about land cover without regard to man-imposed political boundaries or urban definitions. In summer, LANDSAT will show Forest where we know there is a residential area because it cannot "see" through the lush foliage of the neighborhood trees, particularly in older, established residential areas. In newer areas of residential development, where newly-planted trees are not yet well established and do not form a broad canopy, LANDSAT may indeed detect the "urban" area.

Further investigation into the usefulness of LANDSAT in urban areas, as well as the implications of present data, are necessary but beyond the scope of this study. As far as the data presented in this inventory, the term "Urban" should be taken to mean only that area of land which is covered by a concentration of steel or concrete, such as central business districts (Urban Core), built-up industrial areas, and airfields with hard surface runways. The one exception to this general rule is residential areas within metropolitan areas, which tend to show up as "Urban" even though there may not be a large concentration of steel or concrete. This includes both the Urban (Residential) and Urban (Suburban/Agriculture) categories. Occasionally, quarries or strip mines will be identified as Urban, but should cause no great confusion since these areas are normally isolated from urban areas, and can be assumed to belong to the Barren category.

AGRICULTURE

According to Table 10, the identification of agricultural areas is 85% correct. As suggested by the category definitions and Table 12, the majority of agriculture identified by LANDSAT is either vigorous growth or medium to sparse growth of vegetation containing chlorophyll. As seen in Table 12 when the computer misidentified land covers as Agriculture, the two categories misidentified were Rangeland and Forest. In both of these categories there is also vigorous and medium to sparse growth with varying amounts of chlorophyll content, as in the Agriculture category. Confusion between these three categories is, therefore, to be expected, although one would expect to find that only very young, low-growing and sparse areas of forest would be misclassified as Agriculture. It is also, for purposes of this inventory, fortunate that Agriculture is the largest single land use in Ohio, because it is one of the most accurately identified categories, exceeded only by the Forest category at 95%, which itself is the second largest land cover in Ohio.

RANGELAND

Rangeland, the tables indicate, is only correctly identified 60% of the time. The tables also show that the other 40% of the time, LANDSAT misidentifies Agriculture as Rangeland. This agrees with the discussion of Agriculture, where it was pointed out that vigorous to sparse vegetation with varying amounts of chlorophyll could include shrub, brush, and grasses, as well as agricultural crops.

FOREST

According to the tables, the Forest category is the most accurately identified at 95% accuracy. This should not be surprising since forested areas

present a large and uniform area to the eye of LANDSAT. Any other land cover will sharply contrast with forest cover. The only exception is very vigorous and dense agricultural growth, which accounts for 91% of the 5% misclassification of the Forest category.

WATER

Although only eight points were randomly selected which LANDSAT identified as water, (they were all identified correctly), personal observations and other studies have proven the accuracy of the water category. There are, however, several considerations to be made. The most important is that many rivers, particularly the more narrow, will not be identified simply because they are covered by tree canopy, and therefore identified as Forest. A second consideration is that water is identified as Water whether it is found in a river, lake, quarry, construction site after a heavy rain, in the streets, on top of large industrial buildings, or wherever it collects to cover a large area. This aspect should be considered particularly if a surface water inventory is compiled from these data. One further consideration should be made, although it will not affect the statistics contained in this report. Should the occasion arise where the land use of an area is needed by quadrangle sheet rather than by township or county, all water which is shown on the quad will be included in the statistics. This means that quadrangles which include portions of Lake Erie or the Ohio River will reflect that water area in the statistics. For example, the statistics for the Cleveland North quadrangle will show that approximately 80% of the land cover is water (because that much of the quad is in Lake Erie). This would be misleading if one were interested only in the amount of inland surface

TABLE 10

SUMMARY OF VERIFICATION RESULTS

CATEGORY	TOTAL POINTS	NUMBER CORRECT	PERCENT CORRECT	PERCENT OF ALL POINTS SAMPLED	ACTUAL STATEWIDE DISTRIBUTION OF CATEGORIES
Urban	80	52	65	9	5.1
Agriculture	417	354	85	44	48.7
Rangeland	192	115	60	21	14.9
Forest	227	216	95	24	28.6
Barren	13	8	62	1	0.6
Water	8	8	100	1	0.9
Wetland	1	0	0	0	0.0
Totals	938	753	80 (All Points)	100	98.8
				Unidentified	1.2
					100.00

Note: The statistics shown in this table represent the accuracy of the computer classification when compared with the known land cover type. The system for verification is discussed in Schaal (1977).

water, which is included in the 80%. Again, this is not the case for county and township statistics, where the land-water boundary was clearly defined to the computer.

WETLAND

Of the total area, Wetlands are not a significant land use in Ohio, and where they occur, are identified variously as Agriculture, Rangeland, Forest and Water, depending upon how wet they are, and how much vegetation is present.

BARREN

As with Water, the number of randomly - selected points identified by the computer as Barren is small (thirteen). Still, the implications of Table 12 are valid. This table shows that, when land covers were incorrectly identified as Barren, the land covers were actually Urban or Agriculture. The definition for Barren, Stripped/Urban explains the confusion with urban areas. Agricultural areas, although covered by crops on the aerial photography used for verification, may well have been barren, and in preparation for planting at the time of the LANDSAT imagery.

Verification System Used by User RPDO[1]

A project team was selected from the area planning agencies (subcontractors), and an informational meeting was held which included a description of how and why the inventory was developed, a brief description of the Bendix/M-DAS system, the current status of the OSWLUI, and specific work elements within the DECD/OSWLUI Contract. While each of the participants had a strong "land use" background, they were urged, for the purposes of

this study, to develop a "land cover" sense as well. Following this same theme, the spectral characteristics of land cover phenomena were discussed. Although new concepts and terms of land data acquisition were introduced, the participants remained open and enthusiastic.

Discussion with NASA's Land Cover Analysis, Earth Resources Branch at Goddard Space Flight Center, concerning the study produced the following guidelines in developing approaches to verification and use of OSWLUI:

1. Make initial comparison of LANDSAT data and conventional aerial photography because both techniques rely on the same media (observable photograpy);
2. Do not try for an overall land use/cover classification scheme. Rather, focus on topical studies geared to agency problems and needs, such as urban boundary change detection;
3. Look for synoptic views not specific details; and
4. Note areas of urban vegetation coverage as related to the age of housing be type/density.

A major thrust of any verification selected for this study was that it had to require a minimal amount of staff training, it must utilize existing materials and equipment, and it must produce the necessary information for establishing the data's relative reliability within the limited time frame and dollars of the contract. Given these limitations, it was not possible

[1] RPDO Regional Planning and Development Organization.

[2] Acronym for Ohio State Wide Land Use Inventory.

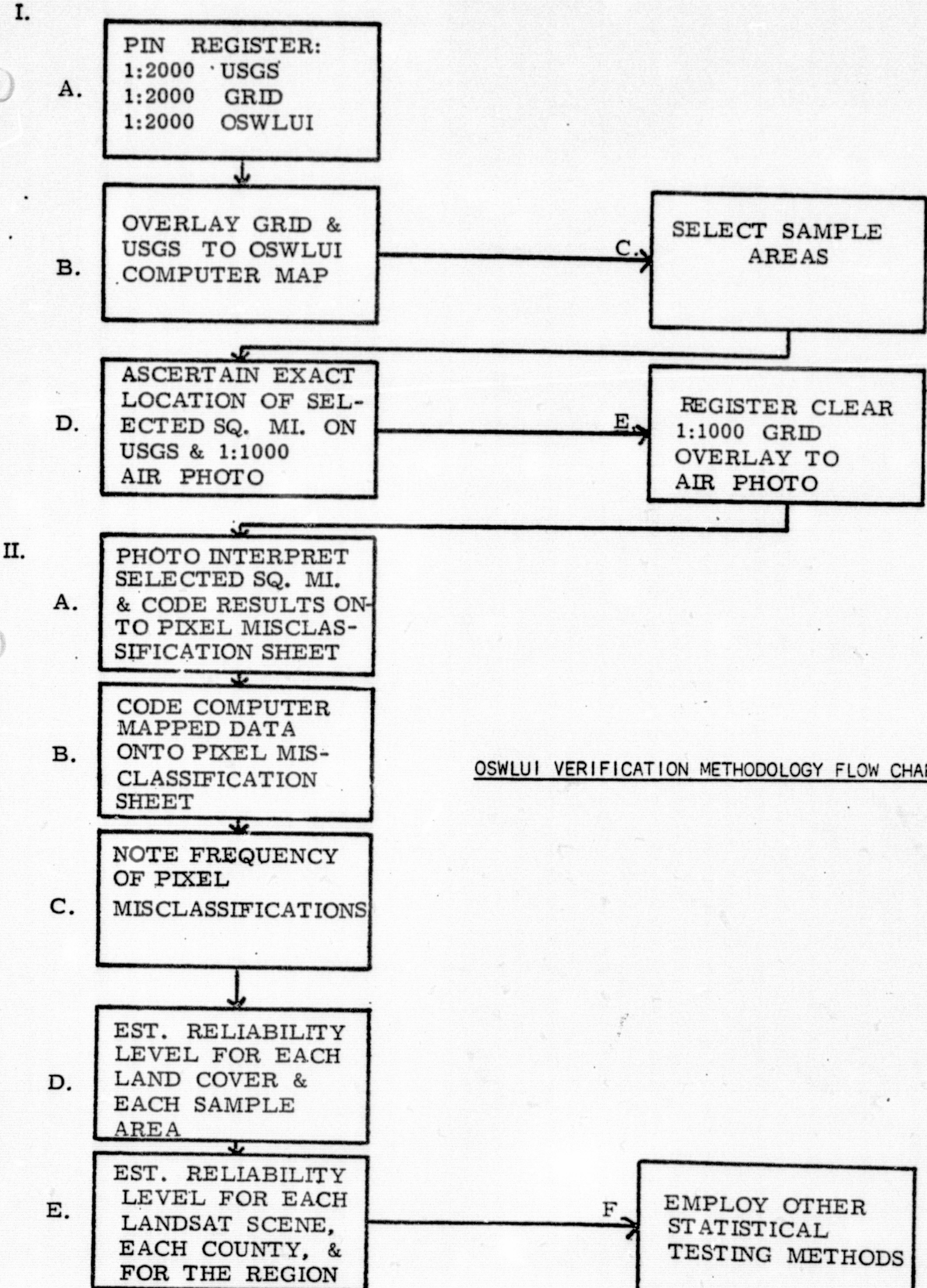
to analyze the entire NEFCO Region (2,049 sq. mi.). Therefore, a methodology was developed which would still fulfill the goals and objectives of this study. In addition, there wasn't sufficient time available to test the verification methodology. Thus, any modifications of the methodology were developed and utilized while the testing was taking place.

At the next meeting, the verification methodology was presented by NEFCO and adopted by the project team. It consists of the following: (Fig. 19)

1. Initial Overlay Procedure
    A. For each sample (test) area, following materials provided:
        1) 1":2000' Grid Overlay
        2) 1":2000' U.S.G.S. Overlay
        3) 1":2000' OSWLUI Computer Map
        4) 1":1000' Grid Overlay
        5) 1":1000' Air Photos
        6) Computer Classification/Photo Interpretation Sheet*
        7) Sample Area Reliability Sheet
    B. To insure proper registration of the base materials, NEFCO pin registered the 1":2000' grid overlay and the U.S.G.S. overlay to the OSWLUI computer map. Because a geometric correction was not performed in any of the 1":2000' computer maps (although it was done on each LANDSAT scene), the U.S.G.S. overlays were registered to the OSWLUI output by matching large bodies of water or stands of vegetation on each of the maps. This technique was somewhat time

*Note: Originally, there was a separate sheet for computer classification and for photo interpretation. These were later deemed unnecessary and were dropped.

Figure 19.



OSWLUI VERIFICATION METHODOLOGY FLOW CHART

consuming, and a percentage of error was possible. For example, certain quadrangles that were primarily agricultural lacked large forest stands or water bodies. In these cases, registration was based on what little forest or water areas were present, and any significant urban features that were evident (such as an interstate highway).

C. For this first phase, NEFCO selected the areas to be sampled using a random selection method. Sample areas are approximately a square mile in size and are located throughout the region. By picking the sample sites randomly, selection bias will be limited; and since the sample areas are distributed throughout the subcontractors' area, it was hoped that the full range of spectral variations for a land cover type would be tested and, therefore, a stratified sample would be obtained. While the sample sites were originally picked totally at random, as the study progressed, it was noted that too often these sites were located over two, three or more photographs. It was decided that too much distortion would be present on the photographs, and that the reliability levels produced would not be correct. Therefore, sample sites were later picked according to their spatial location within the flight line of each photo. The attempt here was to locate a sample site wholly on one photo. This revised selection method was still random in that the spatial location of the photos themselves determined whether or not a particular site could be chosen, not the Interpreter.

D. Using the overlays and maps, NEFCO ascertained the exact location of the selected square mile sample on the 1":1000' air photos. These photos were flown by the Ohio Deaprtment of Transportation during April of 1975. While it would be best to obtain high altitude aircraft photography for a LANDSAT scene which is the same date as the satellite data, in order for the two sources to be the most similar spectrally, it was not readily available for the NEFCO Region. This fact did not present any insurmountable problems in continuing with the verification methodology as it was originally designed.

E. The next step was to register the clear 1":1000' grid overlay to the air photo. This was accomplished by first overlaying the 1":2000' grid and the U.S.G.S. overlays together and locating the sample area. Then three points were chosen. Next, the 1":1000' grid was placed over the photo in such a way that the three selected points were in the same cells as on the preceding grid.

11. Sampling Procedure

A. After locating the square mile to be tested on the aerial photo, this area was photo-interpreted onto the pixel classification sheet (Figure 20), using the categories listed below.

B. After Step A was completed, the computer mapped data for the same square mile was coded onto the same classification

sheet. To aid in classifying the individual pixels into the State's categories, a detailed description of each land cover type was included in the sampling package. Bendix processed the LANDSAT imagery, and the descriptions were provided by them. (See Appendix A).

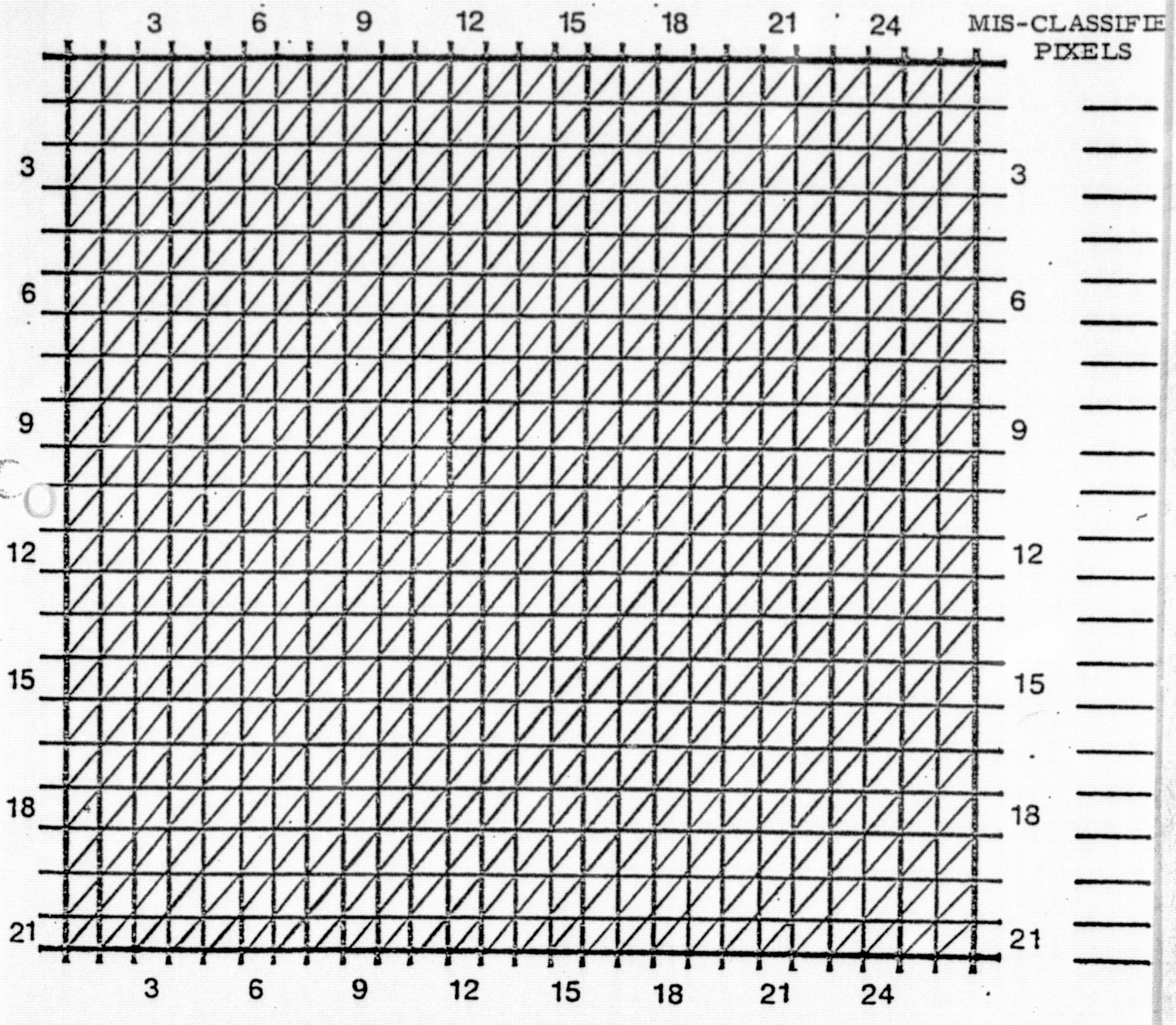
C. The results of the two classification modes were compared, and any differences were noted. The attempt here was not only to note the number of pixels that were misclassified, but to try to detect a consistent computer classification error, for example, Rangeland and Agriculture. Later in this report, the highest occurring misclassifications and correct classifications will be presented and analyzed.

D. From the above sheet, a reliability level (below) was established for each land cover type correctly classified; and an overall accuracy level for each square mile sample was determined. For example; see chart shown on the following page.

FIGURE 20--PIXEL CLASSIFICATION SHEET

QUADRANGLE__________ SAMPLE AREA NUMBER__________ PLANNING AGENCY __________

COMPUTER CLASSIFIED/PHOTO INTERPRETED



TOTAL ______

ORIGINAL PAGE IS OF POOR QUALITY

LEVEL 1 CATEGORIES	TOTAL CORRECTLY CLASSIFIED	TOTAL PRESENT	RELIABILITY LEVEL
Urban	50	75	67%
Agricultural	145	200	73%
Rangeland	25	50	50%
Forest	135	151	89%
Water	45	50	90%
Barren	10	20	50%
Wetland	0	0	0%
Total Pixels	410	546	75%

$$\frac{\text{Total Correctly Classified Pixels}}{\text{Total Pixels}} = \_\_\_\%\ \text{Reliability Level}$$

OR

$$\frac{410}{546} = 75\%$$

When developing the methodology for verifying the OSWLUI, NEFCO placed emphasis on utilizing materials and equipment that most planning (or related) agencies already possessed. While there is equipment (such as the Zoom Trans-fer Scope) on the market which may have enabled NEFCO to sample more areas at a quicker rate, it was agreed that the added expense of said equipment would not have been cost-effective.

NEFCO already possessed 1":1000', 1975 air photos from ODOT for the region, and felt that they were most adequate for determining the OSWLUI's reliability. The pixel-grid verification strategy has been utilized successfully in the past* . . . often the "test site" size is a function of the scale of the photography being used as ground truth. In NEFCO's case, the 1":1000' photography permitted an exact pixel-by-pixel test procedure, for those square mile sample areas. In other areas of the State, the scale of the photography may necessitate using a much larger individual

*Erb, R.B., The ERTS--1 Investigation (ER600). Volume 5: ERTS--1 Urban Land Use Analysis. Houston, Texas: Lyndon B. Johnson Space Center, NASA November, 1974, 121 pp.

81

"cell" size for testing than NEFCO used. This will include a group of pixels rather than one.

The same procedure that NEFCO used (Figure 19) can be followed, however, by the analyst to ascertain the exact location of the test site on the aerial photography and the computer map will be different from what NEFCO used. If a different grid size is developed, it is important that it not become so large that too much data is involved for the verification to be possible or accurate.

This methodology requires a minimal amount of training, and the only experience necessary is some photo interpretive ability (although this can be easily acquired). Once the photo interpretation of the selected sample area is complete, the balance of the work can be finished by a support member of the staff, thereby freeing the professional for other duties.

It is assumed that any other agency that may verify OSWLUI for its area will have up-to-date aerial photography in its office. It is important to have aerial photography whose date is as close to the LANDSAT scene date as possible in order to have accurate ground truth. An alternative to this is field checking, although this is a very expensive endeavor when large areas are involved.

Results of RPDO Verification

An evaluation of the data in the OSWLUI system in the NEFCO study reveals its potential value for using and improving the interpretation capability and mapping accuracy of LANDSAT satellite multispectral data. Preliminary results illustrate that some of the land use/cover patterns in the NEFCO Region have been spectrally separated from a very complex urbanizing environment. Until recently, land cover/use pattern recognition from field work and/or aerial photography has been accomplished mainly by manual, qualitative planning techniques. The introduction of automated approaches (such as OSWLUI via OCAP) has predominantly exploited the statistical nature and two-dimensional shape characteristics of LANDSAT photographic tone patterns. Such things have been useful in the military, forestry, agriculture, and other disciplines where photographic tone patterns are directly related to ground surface patterns of interest. Presently, for a given planning related problem, however, qualitative information is manually derived mainly from planning inferences drawn from pattern analysis of traditional cartographic materials, and only secondarily from tone (LANDSAT) inferences. With this in mind, the following results of the NEFCO study are presented:

Reliability Results for the NEFCO Region

The following results, we feel, accurately reflect the relative reliability of the OSWLUI for this region. The following were considered limiting factors in the analysis of the results:

1. The degree of distortion on the photographs used for ground truth (not considered to be high);

2. The date of the ground truth vs LANDSAT scene;
3. The proper registration of the OSWLUI computer map (see Verification section);
4. Environmental factors -- discussed later in this section.

While each of the above factors played some part in determining how reliable a sample area may be, except for the last, none were expected to significantly affect an are.

TABLE 11

OVERALL RELIABILITY FOR THE NEFCO REGION

	Total Correctly Classified	Total Present	Reliability
Urban	1,979	8,832	22%
Agricultural	20,816	33,195	63%
Rangeland	2,685	13,391	20%
Forest	8,884	15,796	56%
Water	278	679	41%
Barren	76	594	13%
Wetland	0	27	0%
TOTAL	34,718	72,514	48%

As Table 11 shows, the overall reliability level for the region is 48 percent. While this may be considered low, it should be noted that most verification studies deal with a much smaller scale of ground truth than was used by NEFCO. Few studies have based the reliability levels on a pixel-by-pixel verification methodology. Most test sites are an aggregate of different pixels, and the dominant land cover is selected to represent the

test site. This, we feel, cannot be as accurate as a verification methodology which tests each pixel within a sample area "...it is expected that values for correct identification below 50 percent will be very common in complex environments."[1] In total, 133 samples areas were tested (Figure 4). This represents approximately 6 percent of the Region. The low reliability in the urban category is not uncommon, but even if it were to be dropped from consideration, the overall accuracy would only be improved to 51 percent. Therefore, there are other land cover types which are contributing to the low reliability levels. Chief among these is Rangeland. In fact, Rangeland received the lowest reliability score of any cover type. Part of the reason for this is the definitional question of what constitutes "rangeland" in this part of the country. The photo-interpreter has no guidelines, for example, of what percentage crown cover constitutes Forest and when it is Rangeland. As will be noted in the next section, Rangeland is often misclassified with Agriculture. This may indicate the need for additional training sites or that a similar spectral response is being received for Pasture as for Rangeland.

Similarly, Agriculture was being misclassified with Rangeland and may have brought down its accuracy. However, it remained overall the most reliable land cover type, and often scored very high in rural areas. The remaining cover type that was commonly misclassified with it was Forest. One explanation here may be that Agriculture had such a dense amount of vegetation that it would spectrally resemble Forest. This was not expected, however.

1 Lintz, Jr., Joseph and David S. Simonette. Remote Sensing of the Environment. Reading, Mass.: Addison-Wesley Publishing Company, Inc. 1976, p. 453.

Forest and Agriculture, were usually the two highest scoring cover types. On some sample areas, the forested land cover response was quite accurately measured. On others it was not. This may be due to

> "the large amount of spectral variability within a deciduous forest area (e.g., sunlit versus shaded sides of tree crowns being classified into different spectral categories). It is this spectral variability within a deciduous forest area which gives the forest its textural characteristics (thereby making a forest area easily identified and delineated by the human interpreter) but which also makes accurate classification of individual small resolution elements by computer quite difficult."[2]

Water usually received a high reliability score when it was a major component of the landscape, such as a reservoir. The low reliability in interpreting water may be attributed to the fact that the "spectral response of water surfaces could vary greatly because of variations in sun angle or in levels of turbidity."[3] Again, insufficient training sites for ponds and lakes vs reservoirs may also be the case.

The most significant problem that the computer had with barren land cover is that it had trouble with the "Lime Lakes" south of Akron. These "lakes" are large expanses of industrial wastes. If a construction area was large enough, i.e., as in the case of a large subdivision, it was correctly classified.

Wetland was difficult to discern on the aerial photography, and rarely was classified by the computer. Therefore, it is only briefly treated here.

[2]Coggeshall, M.E., R. M. Hoffer and J. S. Berkebil. A Comparison Between Digitized Color Infrared Photography and Multispectral Scanner Data Using ADP Techniques. Laboratory for Applications of Remote Sensing (LARS). Information Note #033174. Purdue Univ., West Lafayette, Ind., p. 2.

[3]Erb, R. B., The ERTS--I Investigation (ER 600). Volume 7: ERTS-1 Urban Land Use Analysis. Houston, Texas: Lyndon B. Johnson Space Center, NASA Nov., 1974, 121 pp.

Analysis of Pixel Misclassification

As a special part of the reliability study, 51 individual sample areas were selected for an analysis of pixels which are computer misclassified. They were then classified as urban, suburban or rural on the basis of the amount of land cover present on the photograph. The actual number of test sites per urban, suburban, or rural "regions" for this analysis is proportional to the percentage found in the region. For example, in this test case, 71 percent of the samples are rural; in the NEFCO Region, 77 percent of the land mass is considered rural. While a stratified sample was also considered, when doing the testing, it was determined that the relative percentages of misclassifications did not change significantly whether there were the same number of sites per "region" or not. The areas used for the analysis are identified in Appendix B.

Within the 27,846 pixels contained on the 51 photographs, 14,149 (or 51 percent) were misclassified. Table 12 indicates that the majority of problems are associated with Agriculture, Rangleland and Forest. For this sample as a whole, these categories are misclassified about 30 percent of the time. The highest individual percentage of misclassification occurs with urban areas where almost 60 percent of the pixels which are classified as Rangeland are photo interpreted as Urban. Review of the photographs indicates that these pixles are Urban from a functional and/or locational aspect, but from a land cover point of view, are often a very low density and/or non-developed in nature.

More common to the overall NEFCO Region's suburban and rural areas, are the misclassifications in the Agriculture, Rangeland and Forest categories

TABLE 12

SAMPLE AREA PIXEL MISCLASSIFICATION, NEFCO REGION

PHOTO INTERPRETATION

COMPUTER CLASSIFIED	URBAN %	AGRI-CULTURE %	RANGE LAND %	FOREST %	WATER %	BARREN %	X %	% OF TOTAL SAMPLE %	TOTAL MISCLAS-SIFIED %	
U		40	31	11	1	17	0	3	300	Rural
		21	60	10	1	8	0	9	237	Suburban
		11	63	7	0	19	0	14	216	Urban
		26	50	10	1	14	0	5	753	Total
A	20		49	30	1	1	0	28	2,818	Rural
	33		34	32	1	1	0	32	843	Suburban
	30		47	22	0	0	0	15	232	Urban
	23		45	30	1	1	0	28	3,893	Total
R	9	76		11	2	2	0	26	2,590	Rural
	57	29		11	2	1	0	33	888	Suburban
	94	2		4	0	0	0	59	914	Urban
	36	51		9	2	1	0	31	4,392	Total
F	4	68	27		0	0	0	38	3,772	Rural
	12	47	35		5	1	0	23	602	Suburban
	39	6	56		0	0	0	1	18	Urban
	6	65	28		1	0	0	31	4,392	Total
W	20	42	2	14		2	0	1	50	Rural
	55	0	36	0		9	0	0	11	Suburban
	91	1	5	1		3	0	8	119	Urban
	69	12	12	4		3	0	1	180	Total
B	16	61	15	8	0		0	1	61	Rural
	26	7	48	12	7		0	2	42	Suburban
	62	9	29	0	0		0	2	34	Urban
	31	31	28	7	2		0	1	137	Total
X	4	78	4	5	6	4		3	338	Rural
	6	34	6	43	6	6		1	35	Suburban
	52	7	31	3	0	7		2	29	Urban
	8	69	6	8	5	4		3	402	Total
								48%	9,929	Rural
								49%	2,658	Suburban
								57%	1,562	Urban
								49%	14,149	Total

*No pixels were classified as wetland in the above sample, consequently, it was not included in this table.

with relatively few problems in the categories of water, barren, or unidentified.

Agriculture

Table 12 illustrates that land cover is many times computer classified as Agriculture, while it is photo interpreted as Urban, Rangeland and Forest. The most significant problems are associated with Rural areas, where almost 50 percent of the time, computer-classified Agriculture is photo interpreted as Rangeland. In suburban types of environments, the problem of Rangleland misclassification appears to be much less (34 percent).

Rangeland

Table 12 shows that computer-classified Rangeland is actually much of the time land cover types involving urban and agriculture land uses. In rural areas of the NEFCO Region, over 75 percent of the computer-classified rangeland was interpreted as being in agricultural production.

Forest

Table 12 points out that, in many cases, computer-classified forest land cover is photo interpreted by planners as Agriculture and Rangeland. The misclassification of Agriculture and Rangeland as Forest is most pronounced in rural areas (70 percent) but is still fairly significant in suburban areas (47 percent). Within urban areas, computer classified Forest cover is interpreted as Rangeland for 56 percent of the misclassified pixels.

Analysis by LANDSAT Scene

The NEFCO region is covered by three LANDSAT scenes. As a minor part of this report, an analysis was done of the relative benfits of one LANDSAT scene vs another. The majority of the region is covered by the July scenes. July scenes are often chosen for crop-type discrimination, but one drawback is that the tree-cover will often hide older residential neighborhoods. from the sensor, and incorrect responses will result. If an April scene is chosen, the user does not have the above problem, but crop types will naturally not be discernable and deciduous (leafless) trees will not be as spectrally obvious as in the summer months.

What is implied here, then, are the merits of temporal categorization of LANDSAT data. Although scene selection is primarily a function of the percent of cloud cover over the area in question, it has been proven that, if temporal LANDSAT data is available, reliability levels will benefit. Table 13 shows that there is little difference in the reliability levels between the April and July scenes.

The October scene's accuracy levels superficially appear to clearly be the least reliable of the three. However, this scene was over middle and upper Summit County, which is urban/suburban, and has the highest topographic changes in the region. It also was one of the hardest cloud-free scenes to obtain due in part to the pollution from the Cleveland area (indeed, recently a new LANDSAT scene for this area was chosen which may yield better results).

TABLE 13

OSWLUI RELIABILITY BY LANDSAT SCENE

TOTAL CORRECT	TOTAL PRESENT	RELIABILITY
	October	
2,491	7,644	33%
	April	
4,970	9,828	51%
	July	
27,257	55,042	50%

CHAPTER II-5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The results of the land use inventorying effort in this contract have brought this state significantly closer to the goal originally set for this program. At this point in time the state has the ability to convert processed land use information derived from LANDSAT satellites into OCAP format data files. These files may be manipulated to provide tailored land use information to a user in very economical fashion. The data base, being computerized in a system with many editing, merging and other file management tools, is a flexible and easily updatable system.

The experience learned in putting this system together will be very valuable and time saving for the next generation inventory. The inventory is in a format becoming increasingly accepted by State and Regional personnel and this factor is important to the effectiveness of an operational information system. Finally, the state now has a current, uniformly derived statewide land use inventory.

It has also become obvious that the methodology used in this work does not provide an operational land use inventory at the reliability level sought in the original goals. More effort must be made to improve the inventory based on machine processing of LANDSAT data. This was not a surprising result and in anticipation of this, other sections of this contract were devoted to pursuing methods to provide increased accuracy

through a hybrid system of methodology. These additional data processing methods would, in the final results, be made compatible with input requirements of the data base management system, which in this case is OCAP.

The system to provide land use/land cover information to users in the state is an excellent vehicle to operationalize an information system using LANDSAT data. The land use inventory is excellent because there exists an immediate need for land use information by state and regional organizations. All people do not use or need land use information; however, to obtain land use most of the generally used processing methodology for other types of information are exercised. Thus redirecting the system to produce other information types is relatively easy one the more generally and more widely used land use/land cover information system is in place.

Recommendations

* Evaluate the present inventory thoroughly with emphasis in two areas: 1) to provide reliability factors and utilize recommendations to users; and 2) to provide information for the improvement of future inventorying programs.
* Institute a long term program (five years) to operationalize a geo referenced information system to address the information needs of HUD 701 Comprehensive Planning, EPA 208 and Coastal Zone Management. Such a program would yield better knowledge of the application of the technology in the environment of state government which is more attuned to operational programs providing services and not programs requiring the flexibility of the research environment.

* Study and develop practical techniques and methodologies to build hybrid operational inventorying system utilizing LANDSAT data and aircraft data with both being interpreted manually and by machine processes.
* Study methodologies to improve the machine categorization of land use/land cover information.

Cost Per Square Mile

The cost per square mile for political boundary digitizing, and file generation and report generating software - $1.00. The cost per square mile for categorization, processing and production of the digital file tapes was approximately $0.90 per square mile. Total cost per square mile is $1.90.

APPENDIX

DEVELOPING A STATEWIDE APPROACH TO TRAINING

Early in the program, the idea of involving the end user in the training portion of the automatic categorication process seemed attractive, for the following reasons:

1. Fulfillment of the need for personnel to develop training information without expanding state staffing, and
2. To involve the potential end user in the product generation.

Several ideas were considered in arriving at the Tutorial Training Package. However, due to a limited amount of time and money, this simple approach was used.

The Tutorial Training Package

The Tutorial Training Package was sent to a number of Regional Planning and Development Organization Offices. The RPDO's were selected because of the more probable usefulness of the inventory at the regional level, and because the RPDO's were more likely to have the required staff. A few RPDO's such as the Ohio Kentucky Indiana (OKI) RPDO's had already experienced the use of LANDSAT data, and the automatic categorization process.

Although the method was not fully developed, two RPDO's sent significant information back - OKI and the Northeast Four County Organization (NEFCO). This information was used by Bendix to assist training the processor.

The Ohio Statewide Land Use Inventory Tutorial Training Package contents are shown in Figure 1.

The Trainer Tutorial Manual gives a description of the LANDSAT program, the categorization process and the importance and characteristics of training information. The Manual is an effort to standardize the thinking about Land Use in relation to LANDSAT processing, and then to teach the trainer in a step by step fashion how to select a good training area and how to document each area for later use by the processor. By reading the manual and using the How To Train section reproduced here, the local agency produced the requested training information and returned it to the State for use in processing the LANDSAT Data.

Please note the several forms and aids that were developed to facilitate the work.

Figure 1.

OHIO STATEWIDE LAND USE INVENTORY

TUTORIAL TRAINING PACKAGE

Contents of Package:

One Set	-	LANDSAT SCENE IMAGERY (Scene of Interest) 1:1 000 000	One Positive Print Band 5. One Positive Print Band 7
One	-	USGS 1:1 000 000 Scale Topographic Index Sheet	
One	-	Landsat/Topo Index Overlay (Scene of Interest)	
One Pad	-	Training Area Forms	
Three	-	Land Use Landcover Listings	
One	-	Trainer Tutorial Manual	

User Provided Items:

USGS 7.5 Minute Quads

Aerial Photographs as Needed

C-2

97

[redacted]

HOW TO TRAIN

Ohio Statewide Land Use Inventory
Procedure for Training Area Selection and Documentation

LANDSAT Scene ID_____ - _______ Track_____ Scene_____ Date ___/___/___

STEP ONE Use an Ohio Statewide Land Use Inventory Land Use Landcover Listing to list the land cover types in your area of scene which make up each land use Level 1 category. Refer to Tutorial Training Manual, section on land use categorization. (Pay particular attention to "spectrally different" land cover types.)

STEP TWO For each land cover type, listed in step one, locate an area of land that is highly representative of this land cover type and is large enough to contain at least thirty (30) pixels.

STEP THREE Using the Index to Topographic Maps of Ohio and the Ohio Statewide Land Use Inventory LANDSAT/Topo Index Overlay for the LANDSAT scene listed in the heading of this procedure, find the 7.5 minute quadrangle for the training area chosen in Step Two. Outline the training area on the quad in earasable marking (pencil, etc.) if desired. Please use four sided figure if possible to outline area.

STEP FOUR Using the Ohio Statewide Land Use Inventory Training Area Form, trace the outline of the training area onto the form (use masking tape to hold form on topo sheet). Also, add a few other features such as road intersection, section lines, etc., to establish location of training area. (Light table helpful).

STEP FIVE Fill in information on the Ohio Statewide Land Use Inventory Training Area Form, including the UTM coordinates nearest the training area. Record any special comments you may have about the training area.

STEP SIX To fill in blank "NW Corner Location of CCT Data", plot the location of the training area on the LANDSAT Topo Index Overlay by placing the overlay on the topo index sheet and approximating the location of the training area within the approprate 7-1/2 minute quad. Next, overlay the LANDSAT Data Locator Grid onto the LANDSAT/Topo index overlay and read the strip, sample and line numbers of the nearest NW Grid intersection to the training area location. Write these numbers into the proper blanks on the training area form.

STEP SEVEN Print your name and organization on the completed form.

STEP EIGHT When all land cover training areas are complete, make copies for your files and send the originals to:

ODECD
P. O. Box 1001
Columbus, Ohio 43216

Please send originals of:

* Land use land cover listing forms

* Training area forms

* LANDSAT/Topo index overlay

(copies tend to become distorted in the copying process).

150

U.S. GEOLOGICAL SURVEY
LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

LEVEL I	LEVEL II
1 Urban or Built-up Land	11 Residential
	12 Commercial and Services
	13 Industrial
2 Agricultural Land	21 Cropland and Pasture
	22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas
	23 Confined Feeding Operations
	24 Other Agricultural Land
3 Rangeland	31 Herbaceous Rangeland
	32 Shrub and Brush Rangeland
	33 Mixed Rangeland
4 Forest Land	41 Deciduous Forest Land
	42 Evergreen Forest Land
	43 Mixed Forest Land
5 Water	Water
6 Wetland	62 Nonforested Wetland
7 Barren Land	72 Beaches
	73 Sandy Areas Other than Beaches
	74 Bare Exposed Rock
	75 Stip Mines, Quarries, and Gravel Pits

OHIO STATEWIDE LAND USE INVENTORY
LAND USE LANDCOVER LISTING

MAIL TO: OHIO DEPARTMENT OF ECONOMIC AND COMMUNITY DEVELOPMENT
P.O. BOX 1001, COLUMBUS, OHIO 43216

LANDSAT SCENE ID 82188 - 15300 TRACK 2 SCENE 2

DATE 7 / 29 / 75

LAND USE LEVEL / LAND COVER COMPONENT	01 URBAN/ BUILT UP LAND	02 AGRICULTURAL LAND	03 RANGE LAND	04 FOREST LAND	05 WATER	06 NON FORESTED WET LAND	07 BARREN LAND
	COMMERCIAL	CORN		EVERGREEN	RIVER		
	INDUSTRIAL	SOYBEANS		HARDWOOD	LAKE		
	PARK	PASTURE		MIXED			
	RESIDENTIAL						

ORIGINAL PAGE IS OF POOR QUALITY

COMMENTS:

TRAINER

ORGANIZATION

102

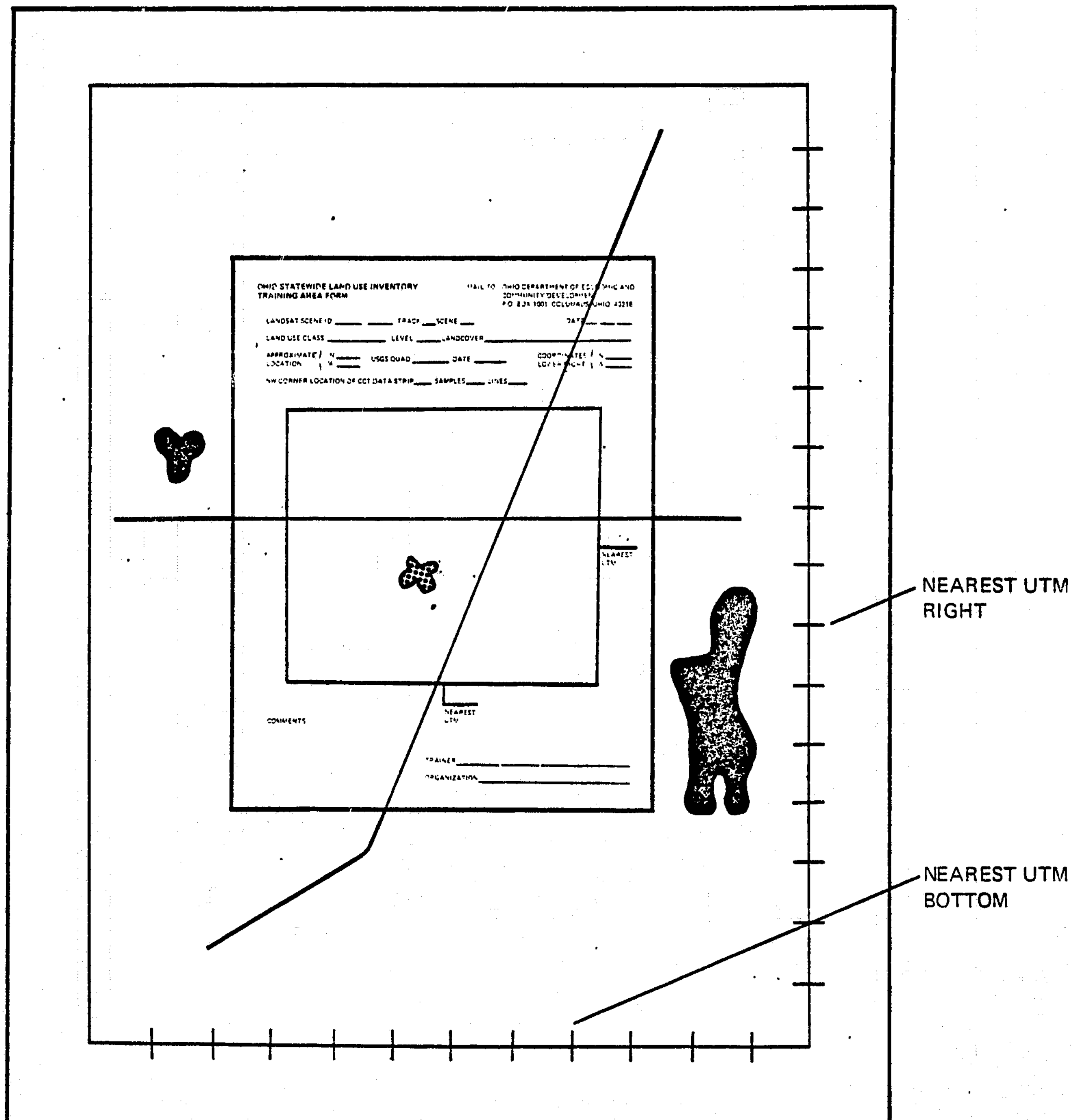
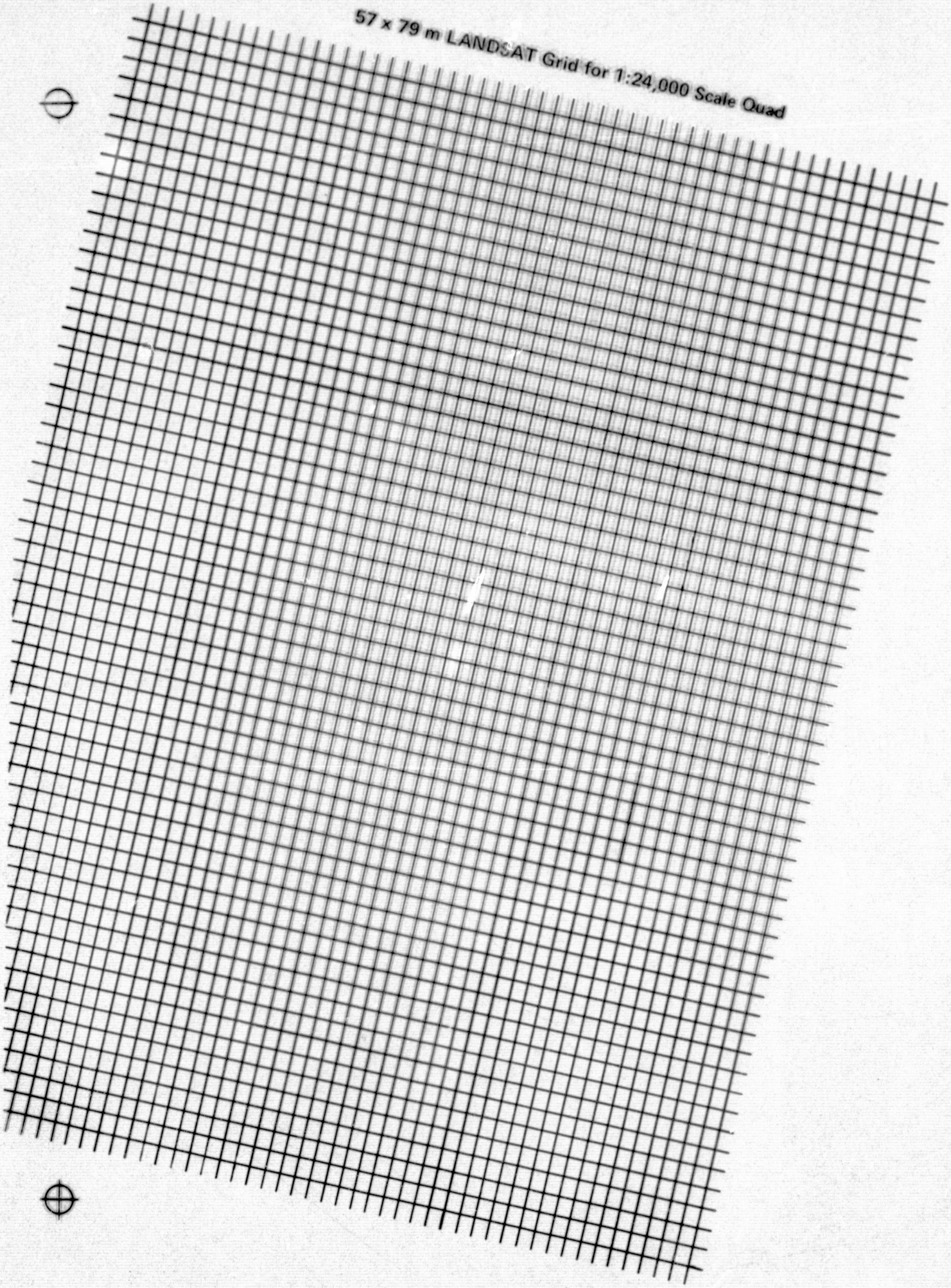


ILLUSTRATION OF TRAINING AREA FORM ON TOPO SHEET


57 x 79 m LANDSAT Grid for 1:24,000 Scale Quad

OHIO STATEWIDE LAND USE INVENTORY
TRAINING AREA FORM

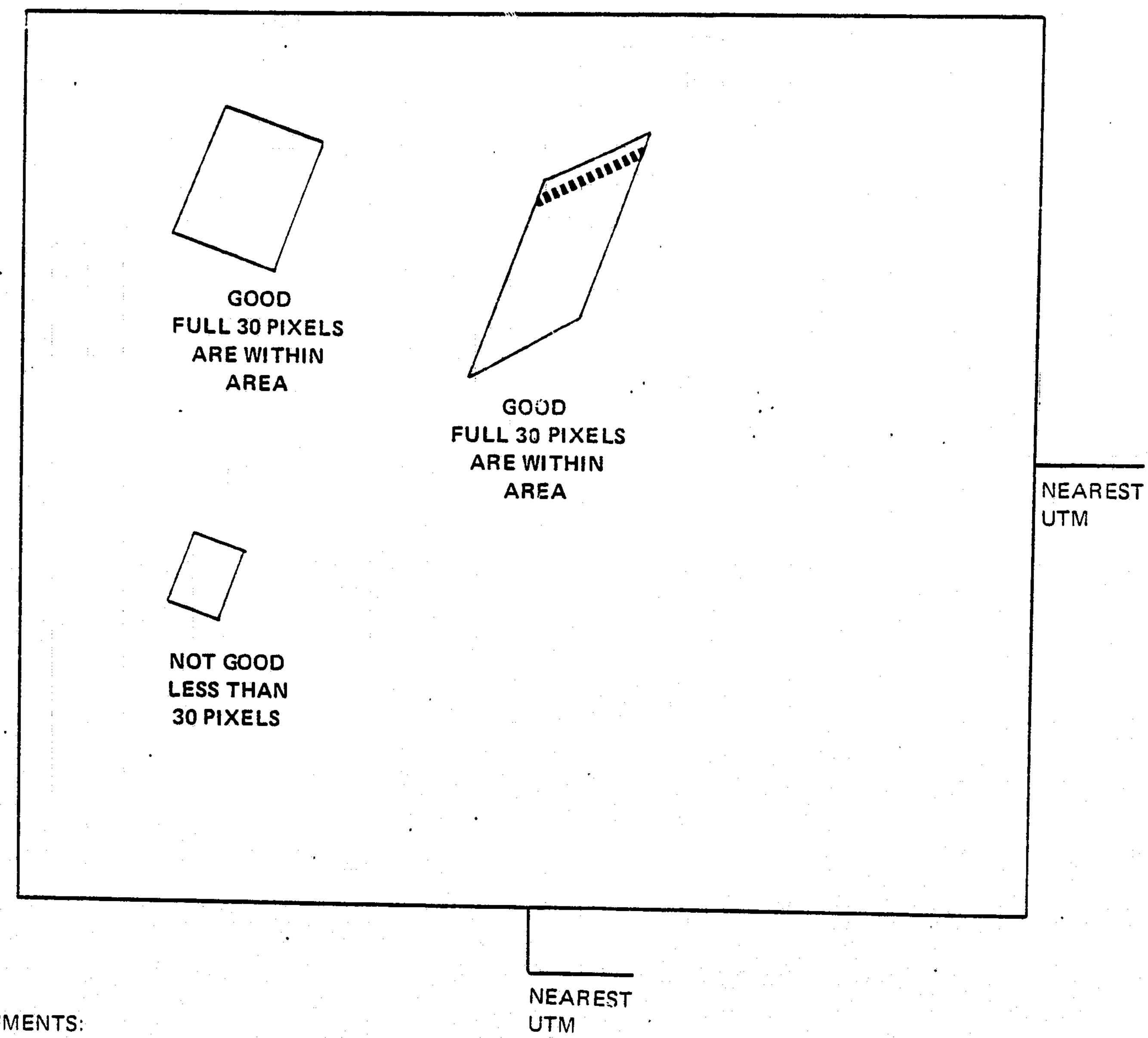
MAIL TO: OHIO DEPARTMENT OF ECONOMIC AND COMMUNITY DEVELOPMENT
P.O. BOX 1001, COLUMBUS, OHIO 43216

LANDSAT SCENE ID ________ - ________ TRACK ____ SCENE ____ DATE ___/___/___

LAND USE CLASS ______________ (LEVEL) ______ LANDCOVER ______________________________

APPROXIMATE LOCATION { N ______, W ______, USGS QUAD ________ (DATE) ________ COORDINATES LOWER RIGHT { N ______, W ______,

NW CORNER LOCATION OF CCT DATA STRIP _____ SAMPLES _____ LINES _____



COMMENTS:

TRAINER ______________________________

ORGANIZATION ______________________________

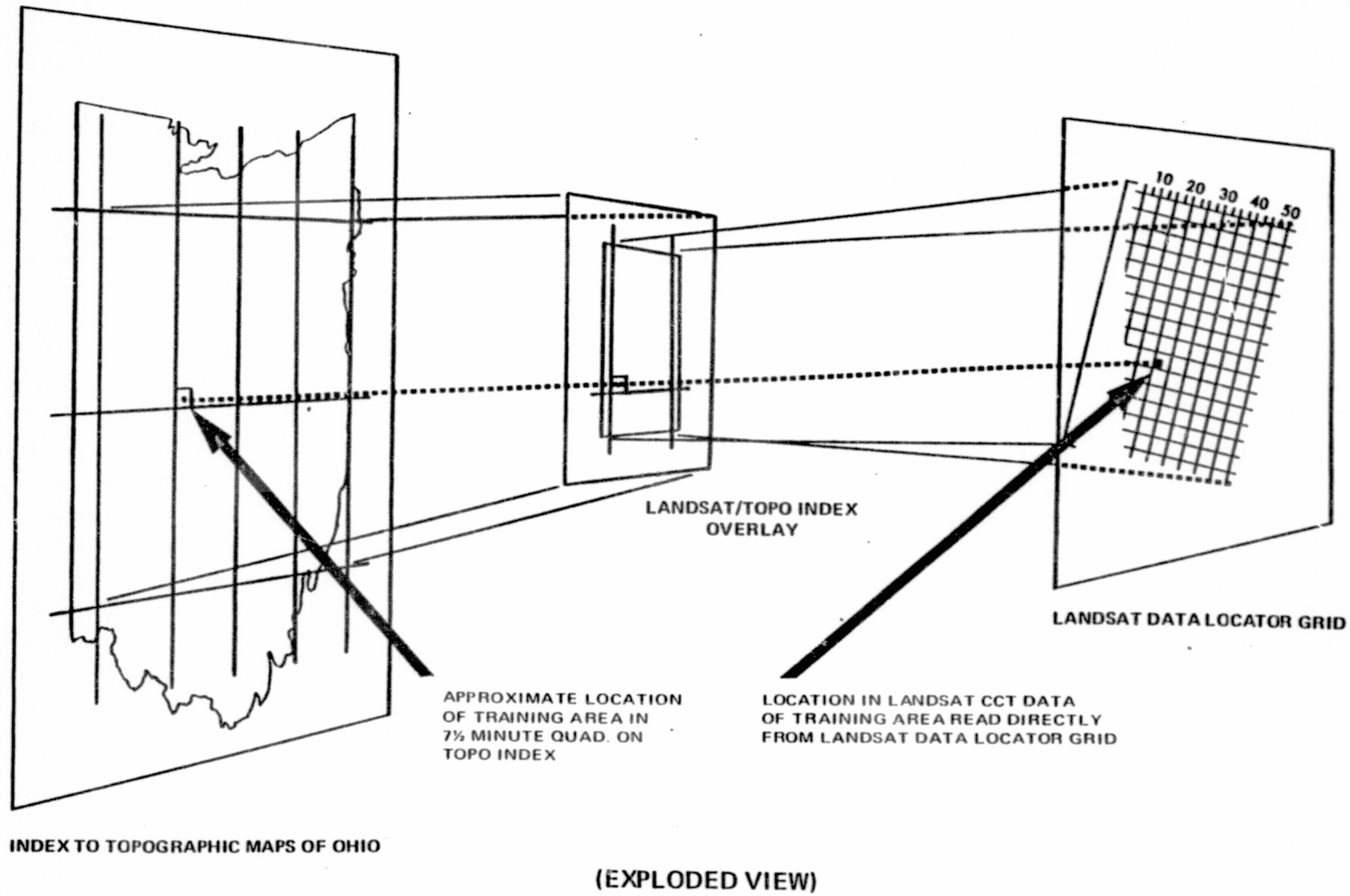


ILLUSTRATION OF METHOD TO LOCATE STRIP/SAMPLE/LINE INFORMATION FOR TRAINING AREAS

OHIO STATEWIDE LAND USE INVENTORY
TRAINING AREA FORM

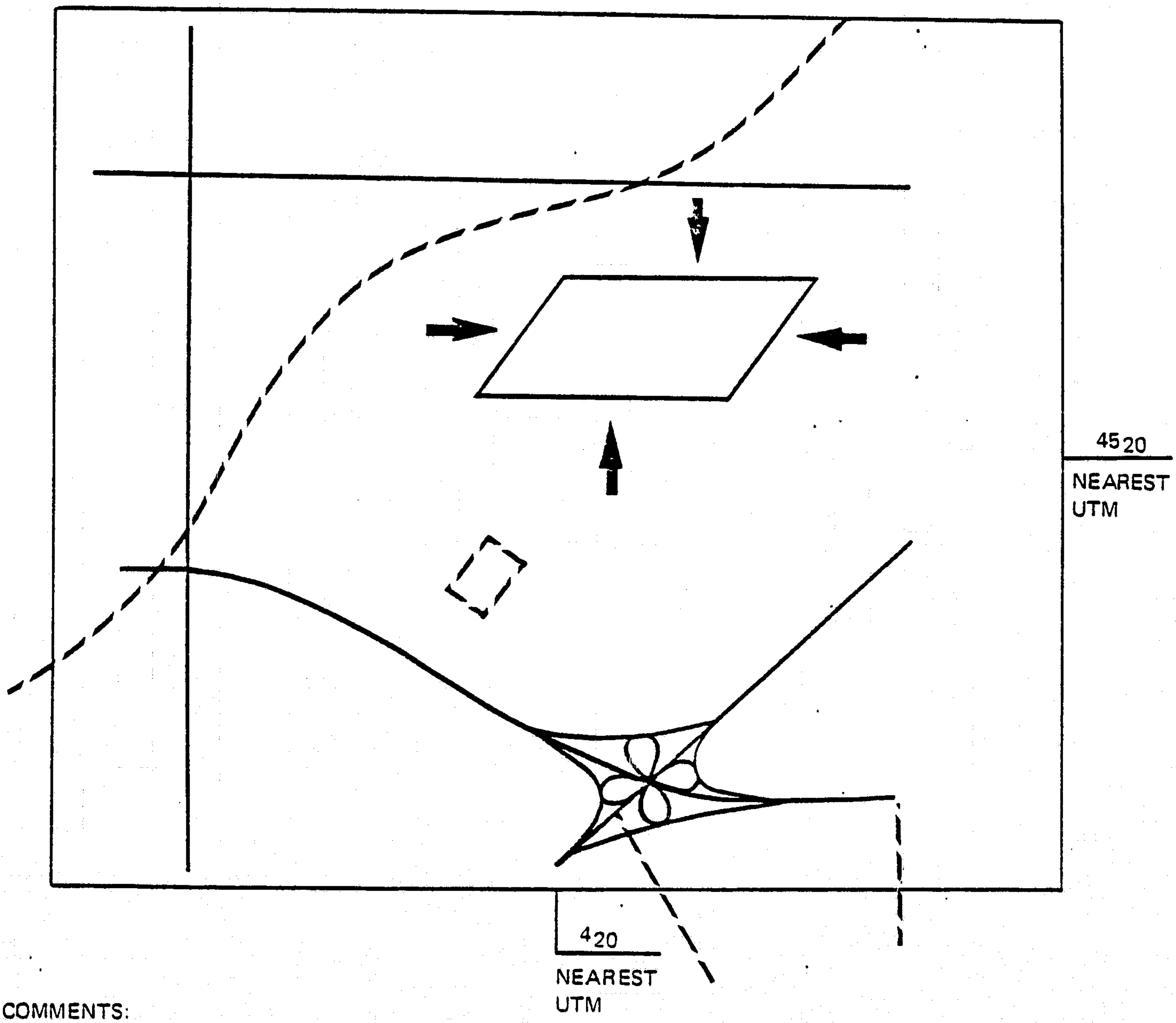
MAIL TO: OHIO DEPARTMENT OF ECONOMIC AND COMMUNITY DEVELOPMENT
P.O. BOX 1001, COLUMBUS, OHIO 43216

LANDSAT SCENE ID 8188 - 15300 TRACK 2 SCENE 2 DATE 7 / 29 / 75

LAND USE CLASS URBAN/BUILT UP (LEVEL) 1 LANDCOVER COMMERCIAL

APPROXIMATE LOCATION N 40° 50', W 81° 57', USGS QUAD WOOSTER (DATE) 1961 COORDINATES LOWER RIGHT N 40° 45', 00", W 81° 52', 30"

NW CORNER LOCATION OF CCT DATA STRIP 2 SAMPLES 750 LINES 600



COMMENTS:

TRAINER ______________________

ORGANIZATION ______________________

U.S. GEOLOGICAL SURVEY
LAND USE AND LAND COVER CLASSIFICATION SYSTEM FOR
USE WITH REMOTE SENSOR DATA

LEVEL I	LEVEL II
1 Urban or Built-up Land	11 Residential 12 Commercial and Services 13 Industrial
2 Agricultural Land	21 Cropland and Pasture 22 Orchards, Groves, Vineyards, Nurseries, and Ornamental Horticultural Areas 23 Confined Feeding Operations 24 Other Agricultural Land
3 Rangeland	31 Herbaceous Rangeland 32 Shrub and Brush Rangeland 33 Mixed Rangeland
4 Forest Land	41 Deciduous Forest Land 42 Evergreen Forest Land 43 Mixed Forest Land
5 Water	Water
6 Wetland	62 Nonforested Wetland
7 Barren Land	72 Beaches 73 Sandy Areas Other than Beaches 74 Bare Exposed Rock 75 Strip Mines, Quarries, and Gravel Pits

Volume 3

THE OHIO LAND ALLOCATION MODEL

FINAL REPORT

-108

FINAL REPORT: Development of a Multi-Disciplinary ERTS User Program in the State of Ohio

PERFORMED FOR: Goddard Space Flight Center

CONTRACT NUMBER: NAS5-22399

DATE: September 5, 1977

PRINCIPAL INVESTIGATOR: Paul E. Baldridge
Assistant Director
Department of Ecnomic and Community Development
P.O. Box 1010
Columbus, Ohio 43216

PROGRAM MANAGER: Thomas A. Martin
Program Manager
Remote Sensing Programs
Department of Economic and Community Development

INVESTIGATORS: Volume Three

Ohio Department of Economic and Community Development
Mr. Charles Weber

Dr. Oscar Fisch, Consultant

Mr. Stephen Gordon, Consultant

This research was made possible through the funding of the National Aeronautics and Space Adminstration Goddard Space Flight Center under a contract, NAS5-22399 to the State of Ohio.

ACKNOWLEDGMENTS

We would like to acknowledge the contributions of several people without whom this project would not be possible. Throughout the project, Harvey Curran helped to gather and analyze data, and played a major role in programming the final models and performing the final LANDSAT data tests. In Phase I and II, the assistance of Richard Hoffman and Karen Wilson in data gathering and analysis was invaluable.

We must also give credit for help from Tom Flocken and Yang Soo Yun of the Ohio Department of Natural Resources who aided in our evaluation of the LANDSAT data.

Finally, we must credit Tom Martin of the Ohio Department ofEconomic and Community Development for his help as project manager, and the National Aeronautics and Space Adminstration for funding the research. None of the above are resonsible for any errord herein, which, alas, must fall to the authors.

Volume 3

TABLE OF CONTENTS

112

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

115

LIST OF TABLES (Continued)

116

INTRODUCTION

This report is the final report relating to the merging of LANDSAT and Socio-Ecnomic data in an Allocation Model. The general purpose of this research is to define a set of land use models relating socio-ecnomic characteristics to change in land use as measured by tax information and interpretations of LANDSAT data provided to the State of Ohio through the statewide Land Use Inventory portion of this contract.

Specifically, this project has:

1) Reviewed the current state-of-the-art in land use modeling.
2) Reviewed and assembled available data for the land use modeling effort in Ohio.
3) Reviewed the potential for using LANDSAT statelite imagery for land use study.
4) Formulated a set of models relating to tax base in Ohio counties by type of use (residential, industrial, commercial, agricultural) to population, employment and agricultural production.
5) Prepared data, through aerial photo interpretation, to test the reliability of the LANDSAT interpretations for Ohio for use in a similar modeling framework.
6) Performed error testing of the LANDSAT data using information in Step 5.
7) Tested LANDSAT based land-use models for Ohio counties.
8) Provided a computer program and documentation for all models whose reliability was found acceptable.

Some of these tasks were performed during Phase I and Phase II of the project, and were summarized in detail in previous reports.[1] The results of these portions of the work will be summarized in the present report but not given in as great detail.

The remaining results are presented here for the first time.

Chapter I summarizes the activities and results of Phase I. This includes the initial set of socio-economic data, and the models relating tax base data as a proxy for land use to the socio-economic variables.

Chapter II provides a summary of Phase II. This includes details of the agricultural sector models, and the method of collection of data for the final phase.

Chapter III of this report details computer models which were derived and provides detailed documentation of these models. The erroranalysis of LANDSAT data is presented, along with the results of the analysis of LANDSAT land cover data as an input to land use modeling in Chapter IV. The LANDSAT data analysis has provided the opportunity for the creation of a rather generalized procedure which may be used to predict the results of modeling efforts using the various interpretation system results. The potential importance is in the evaluation of interpretation systems as to their readiness for use in modeling efforts involving socio-economic data.

[1] The Ohio Land Allocation Model: Report on Phase I by Oscar Fisch and Steven Gordon and The Ohio Land Allocation Model: Report on Phase II by Oscar Fisch and Steven Gordon.

CHAPTER III - I

SUMMARY OF PHASE I

A number of activities were undertaken for Phase I of the project. The first task was to review models of land use change developed for other areas. This was necessary in order to take advantage of the experiences of other researchers and to put the current modeling effort into perspective. These models are reviewed in the first section of this report.

Given an overview of land use models, the second major task was to review the data available for the current modeling effort. A number of data sources have been assessed thus far. These include data from the State Board of Tax Appeals on land parcels and assessed value in various land categories, census information, employment data, and land use information. Each of these data sources was reviewed in various parts of the report with regard to the quality, comparability, and usefulness of the data in the modeling effort.

Next, a review was made of the potential uses of LANDSAT statelite imagery in land use study. Past attempts to utilize these data were presented. The possible uses of the data in Ohio were reviewed along with some of the potential problems associated with using it in a modeling effort.

Land Use Modeling- A number of conclusions were drawn in Phase I with regard to the problems associated with past efforts at land use modeling. Foremost among these is a lack of understanding of the process of land conversion. Modeling efforts have had to depend on subjective decisions relating

to the amount of land conversion associated with the growth of industry and population. A large error is therefore introduced into the modeling process. For this reason, any future research should first identify the scale and nature of the land conversion process before proceeding to allocate actual changes in use to particular areas.

Another common defect of land conversion models is their failure to consider the complex competition among land uses in urbanizing areas. All the models allocate changes to different uses sequentiall, without regard to the interrelationships among uses. It remains impossible to completely model the complex land system. However, an effort must be made to asses the interconnections among land uses in the conversion process in several types of urban and rural areas.

The final, and perhaps most critical, problem associated with land use modeling is the very poor data base available for most areas. Each of the studies cited in Phase I notes problems with the modeling process associated specifically with the limitations of the data. These problems range from the lack of information of land use over time to problems with data on land value, population, land quality, and other socio economic variables.

Land Use Data in Ohio

Given the major problems associated with data on land use cited in other studies, the first task of the present research effort was to undertake an inventory of land use data in Ohio. In order for a predictive model of land use change to be formulated, a consistent data base must be compiled. Such a data base must be accurate, have the same land use categories, and must be compiled for most than one date.

Unfortunately, traditional land use inventories performed as a portion of the comprehensive planing process vary greatly in their accuracy, consistency, and frequency. Nevertheless, these are generally the only source of land use data available for a modeling effort. A review of all the comprehensive plans undertaken in Ohio showed that the land use data base in indeed poor. Table 1 summarizes the results of this survey.

As can been seen from the table, a large number of counties have no land use data available. Thirty-three counties are included in this category. Of the remaining counties, eight counties have land use information in map form only. The other counties have data complied on the acreage devoted to particular land uses in at least five categories - agricultural, residential, commercial, industrial, undeveloped. Only five counties have data available in more than one year or from more than one source. One can see the wide variation in the time distribution of these data.

It is evident from this review that land use inventories are not an adequate data base from which to derive a model of land use change. It is for this that LANDSAT statelite imagery is being considered for this purpose. The characteristics of this data base is given below.

LANDSAT Data Review

One potential answer to the unavailability of land use data is the use of LANDSAT (Land Satellite) imagery of land cover. This data has been utilized for several types of land use studies and its advantages and disadvantages have been delineated. According to one study,

The advantages are:

1. High speed processing
2. Frequently obtained new data
3. Unbiased and uniformly repetitive classification
4. Production of print-out maps at a large map scale at relatively low cost (once the system becomes operational)

TABLE 1

Land Use Inventories Available For Ohio Counties

County Name	Land Use Data*	Date	County Name	Land Use Data*	Date
Adams	No data	--	Licking	No data	--
Allen	Acreage data	1965	Logan	Acreage data	1968
Ashland	Map only	1972	Lorain	Acreage data	1957,1963
Ashtabula	Acreage data	1971	Lucas	Acreage data	1970
Athens	Acreage data	1969	Madison	No data	--
Auglaize	No data	--	Mahoning	Acreage data	1963
Belmont	No data	--	Marion	Map only	1965
Brown	No data	--	Medina	Acreage data	1957
Butler	Acreage data	1965	Meigs	Acreage	1971
Carroll	Unavailable	--	Mercer	Acreage	1969
Champaign	Acreage data	1968	Miami	Acreage	1965
Clark	No data	--	Monroe	Acreage	1972
Clermont	Acreage data	1965	Montgomery	Acreage	1965
Clinton	No data	--	Morgan	No data	--
Columbiana	Map only	1967	Morrow	No data	--
Coshocton	Acreage data	1968	Muskingum	No data	--
Crawford	Acreage data	1971	Noble	No data	--
Cuyahoga	Acreage data	1959,1971	Ottawa	Acreage	1970
Darke	Acreage data	1965	Paulding	No data	--
Defiance	No data	--	Perry	Map only	1965
Delaware	Acreage data	1969	Pickaway	No data	--
Erie	Acreage data	1969	Pike	No data	--
Fairfield	Acreage data	1973	Portage	Acreage	1959
Fayette	Acreage data	1964	Preble	Acreage	1965
Franklin**	Map only	1964	Putnam	No data	--
Fulton	Acreage data	1970	Richland	No data	--
Gallia	Acreage data	1972	Ross	No data	--
Geauga	Acreage data	1962,1970	Sandusky	Acreage	1972
Greene	Acreage data	1965	Scioto	No data	--
Guernsey	Acreage data	1964	Seneca	No data	--
Hamilton**	Acreage data	1965	Shelby	No data	--
Hancock	Acreage data	1962	Stark**	Acreage	1962
Hardin	No data	--	Summit	Acreage	1959
Harrison	Acreage data	1968	Trumbull	Acreage	1959
Henry	Unavailable	--	Tuscarawas	No data	--
Highland	No data	--	Union	Acreage	1968
Hocking	Acreage data	1966	Van Wert	No data	--
Holmes	Acreage data	1969	Vinton	Acreage	1969
Huron	No data	--	Warren	Acreage	1965
Jackson	Acreage data	1966	Washington	No data	--
Jefferson	No data	--	Wayne	No data	--
Knox	Acreage data	1972	Williams	Acreage	1965
Lake	Acreage data	1957	Wood	Acreage	1960
Lawrence	Acreage data	1971	Wyandot	No data	--

* Data may be available compiled in statistical format (acreage type), in the form of a map, or unavailable.

** Data available from other sources.

5. The inherent digitizing of land-use data retrievable in virtually any form or combinations of forms.[1]

As this list of advantages states, the major benefit of LANDSAT imagery is its repeatibility in time and space and compatibility with computer processing. The ERTS-1 satellite passes over the United States with a frequency of once in eighteen days. The cost of compiling and interpreting the LANDSAT data available on computer compatible tapes (CCT's) compares favorably with the cost of convential aerial photography.[2] Interpretation of land cover is accomplished through the classification of picture elements or pixels based on multispectral data. The data on four bands of the spectrum available from the LANDSAT satellite is first grouped using cluster analysis. This defines groups of pixels with similar spectural signatures. Then, through the identification of areas of known land use, each spectral signatures is assigned a land use category. All pixels with spectral signatures within a statiscally acceptable range of these values are tabulated with the equivalent land use. Since the data is handled, analyzed, and stored on the computer, convenient mainpulation for use in many situations is possible.

The question which must be answered with regard to the current project is whether or not and in what way LANDSAT data can be utilized to model land use change in Ohio.

Several studies give an indication of the potential uses of, and problems with these data. Joyce illustrates several examples of the use of ERTS data in land use studies one of which recorded land use changes around Washington, D.C.[3] In addition, Joyce points out the need to tie ERTS land use data to other socioeconomic data bases.

Wray summarizes several project which seek to combine ERTS data, high altitude photography, and socioeconomic data bases.[4] One major project entitled the "Census Cities" Project will tie ERTS observations with data from the 1970 Census of Populaiton for several major metropolitan areas in th U.S. This information will be utilized to help monitior areas in these urban areas and should serve to aid planners in the delineation and control of urban growth.

These brief examples illustrate the great potential of ERTS imagery for the study of land use, At the present time, however, such studies are not without their technical problems. As Ellefson et al. point out above this data:

The disadvantages are:
1. The inability of the system to discriminate with consistent success between functionally dissimilar but spectrally similar land uses.
2. The impossibility of detecting parcel ownership.
3. Generalization be resolution element: at 80 meter resolution the complexity of the urban landscape cannot be shown fully.
4. Identifications dependent on vegetation vary seasonally.
5. Uncontrollable incidence of cloud cover.[5]

In a study using conventional interpretation methods which satellite data, Vegas showed that " ... it was found that although major categories are reasonably well defined from ERTS, a significant number of lesser features were incorrectly identified or unidentifiable."6

He goes on to say that

Therefore, only cells that fall upon a uniform, homogeneous area will give representative readings. In essence, for ERTS data, any target area of less than 79 meters (260 feet) in diameter cannot give a true representation in its recorded signal but is averaged with the adjacent cell automatically.[7]

The higest proportion of errord were found in urban areas. It is for this reason that Ohio-Kentucky-Indiana Regional Council of Governments found that "Urban land use types were similarly confused in LANDSAT categories. "8 Due

to the detailed land use categorization requirements of this agency, LANDSAT data had to be supplemented with aerial photo interpretation and field checks.

It is also for these reasons that Wiedel and Kleckner recommend prior ground reconnaissance and follow-up field checks and air photo checks for detailed land use studies using ERTS data.[9] Other studies using computer interpretation of ERTS data have found similar problems.[10] Certain rural and urban uses with similar spectural signatures were not distinguished from one another.

Several methods of dealing with these misclassification problems are currently being developed. One group of researchers has found that utilization of data from two contrasting seasons substantially reduces the errors in identification between urban and rural categories.[11] Another study has geographically subdivided the urban and rural areas automatically programmed two sets of allowable categories.[12] These and other techniques currently being studied promise to improve the accuracy of LANDSAT interpretation.

One additional technical problem with the utilization of ERTS data is related to the overlay of satellite images for two different years. Due to the distortion of the original data pixels and the subsequent rescanning, readjustment, and reclassification, an error in the range of ± 1 pixels in ground orentation may result. [13]

Thus, there are two major types of errors which occur with LANDSAT data, errors which are due to misaligment (hereafter called Error 1) and errors due to misclassification (hereafter called Error 2). Although ERTS data offers may potential advantages, it is unclear whether or not these errors would allow one to formulate a reliable, predictive model of land use change. The first priority in the study of land use with ERTS data in Ohio must therefore be a characterization of the order of magnitude of each these errors. A quanti-

fication of these errors will delineate the overall reliability of these data and will also serve to indicate where improvement in the techniques related to LANDSAT data analysis are required. The use of LANDSAT in the formulation of predictive land use models must await the quantification of these errors. A major goal of this project is, therefore, to quantify Error 1 and Error 2. This was a major focus of the final phase of this project.

A Standard Set of Land Categories

A number of alternative land use classification schemes are possible. Before procedding to study land use change in Ohio, it is important to establish a standard set of land use categories. One such set has been suggested by the U.S. Geological Survey.[24]

The U.S.G.S. proposes nine "Level I" categories for use with remote sensor data. These are:

(1) Urban and Built-up Land

(2) Agricultural Land

(3) Rangeland

(4) Forest Land

(5) Water

(6) Nonforested Land

(7) Barren Land

(8) Tundra

(9) Permanent Snow and Icefields.

These categories may futher be subdivided into more specific "Level II" categories. For the purposes of the present study, the only Level I category for which a finer breakdown is required is "urban and built-up land". Changes within other categories to be used, if available, are:

Urban and Build-up Land

(1) Residential

(2) Commercial

(3) Industrial

(4) Extractive

(5) Major Transporation, Communication, and Utility Corridors

(6) Institutional

(7) Mixed Urban (urban uses not resolvable)

(8) Open Spaces and Other Urban

Also, major discernable patterns of development (e.g. strip and clustered) will be analyzed.

As previously discussed it will not be possible to accurately determine all of these categories from LANDSAT. Therefore, large scale (i.e., high resolution) aerial photography will be utilized to augment LANDSAT data in order to obtain a finer level of land use categories. The minimum urban categories which will be exarcted from aerial photographs are:

Residential

Commercial

Industrial

Major Transporation. Communication, and Utility Corridors

Undeveloped.

Data on these categories should prove adequate for all tasks undertaken in Phase II of this project.

THE LAND CONVERSION MODELS

The land use models derived in Phase I include models of tax assessed value in the residential, commercial, and industrial land use categories and the number of tax parcels in each of these categories the data which were input for these models are discussed below following which the statistical results of the modeling effort are given.

The quality of land use information in Ohio has already been reviewed above. Given the poor quality of such data an attempt was made to find other sources of related information in tax records. The first major source of such data which was reviewed are data available from the State Board of Tax Appeals.

One advantage to utilizing these data are their continuous availability over time. Data on assessed value for land and buildings are available for all 88 Ohio counties in five categories - residential, commercial, industrial, agricultural, and mining. A model constructed from such data would be an indirect indicator of changes in land use over time. A side benefit of such a model is the potential prediction of tax base changes over time. Thus, these data from 1962, 1967, 1972, 1974, and 1975 were collected, coded and placed on computer tape. The analysis of these data are discussed below in the section on Model 2.

Another subset of tax data are available on parcels in each of the above use categories. Agricultural acreage is also given. The number of parcels are potentially more directly translatable into actual acreages. Unfortunately, these data are only available from 1967 on for 36 counties in Ohio. These counties are shown in Figure 1. These data have been coded,

FIGURE I.

MAP OF 36 COUNTIES WITH TAX PARCEL DATA AVAILABLE

1·31

punched, and placed on computer tape. Their analysis is given under the discussion for Model 1.

Given this set of tax data, an effort was made to establish whether or not parcel data could be translated into actual land use categories. It was thought that a sample of parcel sizes could be taken in each county. This would give a mean distribution of sizes which could then be applied to the parcel data to transform it into actual acreages. Thus, an investigation was made of the manner in which data on tax parcels is stored by county tax authorities. It was found that simpling of the tax records could give an indication of actual acreage in each tax category. A sampling program for three counties in Ohio was carried out during Phase II of the project and is summarized in Chapter II.

One idiosyncrasy of the tax board data is the categorization of land uses. For tax purposes, a residential parcel is only one with fewer than six units. All other, larger residential units are classified as commercial. Again, an investigation was made into potential methods of subdividing the commercial category and residential components. One source of information investigated was census data on multiple housing units. It was found that the census categorizes multiple units of five or more. This of course, does not correspond to the six or more. This of course, does not correspond to the six or more categorizations made for tax purposes. Similarly, building inspections are carried out for buildings with four or more units making use of this data impossible. Thus, the tax data had to be utilized in the models in their present, unadjusted format.

The next major data base investigated was census materials. The Censuses of Business, Retail Trade, Wholesale Trade, and Manufacturers were carried out in 1967 and 1972. Data included employment and output by industry by county. Here, it was found that due to rules on disclosure on information,

many pieces of data were missing, even at two digit SIC code level for counties. THis makes utilization of this data base very difficult.

Another census related data source which has been investigated is County Business Patterns. This publication is annual and presents data on employment by industry by county. Although there is less missing data, the problem with County Business Patterns is that the most current information is for 1973.

Thus, the next source of economic data investigated was information on employees covered by unemployment insurance available from the Ohio Bureau of Employment Services. The major advantages of these data is their availability on an annual basis through 1975. This represents the most current set of information. Correspondence between covered and non-covered employees is good except for government workers. This is illustrated by Table 2.

These data have been assembled for 1962, 1967, 1972, 1973, 1974 and 1975. Coupled with 1972 and 1973, estimates of population by the Bureau of the Census, this information has been used to assemble an economic profile of Ohio. In this way, one can see those areas where the most land use changes are probably occurring. Tables 3 to 7 summarize the analysis of these data. Counties were ranked based on the changes in total employment, employment in each category, population, and overall change for the period in question.

These tables illustrate a number of trends in Ohio's economy and population. First, one cna see that the largest amount of growth is concentrated in and around the largest SMSA's - Cleveland, Columbus, Cincinnati and Toledo.

Two counties, Cuyahga and Hamilton, had large gains in employment and small gains in population. In constrast, surrounding counties experienced a large amount of population growth. This illustrates the effect of commuting and suburbanization. Finally, it should be noted that service, financial, and trade employment, the non-basic industries, were the largest gainers in the

TABLE 2

Difference between Covered Employment and Total Employment in Ohio, 1973.[a]

Employment (1000's)

Sector	Total	Covered	Difference	% Difference
Total	4112	3503	609	14.8
Mining	23	23	0	0
Contract Construction	167	168	-1	-0.6
Manufacturing	1422	1424	-2	-0.1
Transp. & Util.	224	190	34	15.2
Wholesale & Retail	857	853	4	0.5
Finance	174	168	6	3.4
Services	648	553	95	14.7
Government	596	115	481	80.7
Total w/o Govt.	3516	3388	128	3.6

[a]Employment covered by unemployment insurance. Data from Ohio Bureau of Employment Services, 1973. Total employment data from the Statistical Abstract of the United States, U.S. Dept. Commerce, Bureau of the Census, Table 565, p. 346.

TABLE 3

ECONOMIC PROFILE OF OHIO:

VARIABLE NAMES

TOT-72	1972	
TOT-74	1974	TOTAL EMPLOYMENT
DEL-TOT	Change in	
POP-72	1972	
POP-73	1973	POPULATION
DEL-POP	Change in	
E01-72	1972	
E01-74	1974	MINING EMPLOYMENT
DEL-01	Change in	
E02-72	1972	
E02-74	1974	CONTRACT CONSTRUCTION EMPLOYMENT
DEL-02	Change in	
E03-72	1972	
E03-74	1974	MANUFACTURING EMPLOYMENT
DEL-03	Change in	
E04-72	1972	
E04-74	1974	TRANSPORATION & UTILITIES EMPLOYMENT
DEL-04	Change in	

TABLE 3 (Continued)

ECONOMIC PROFILE OF OHIO:

VARIABLE NAMES

E05-72	1972	
E05-74	1974	WHOLESALE & RETAIL TRADE EMPLOYMENT
DEL-05	Change in	
E06-72	1972	
E06-74	1974	FINANCE, INSURANCE AND REAL ESTATE EMPLOYMENT
DEL-06	Change in	
E07-72	1972	
E07-74	1974	SERVICES EMPLOYMENT
DEL-07	Change in	

TABLE 4

SUMMARY STATISTICS, ECONOMIC PROFILE OF OHIO

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

VARIABLE	N	MEAN	STANDARD DEV	VARIANCE	SUM	CORRECTED SS	LOW	HIGH	C.V. %
TOT_72	88	37580.227273	88798.611375	0.788519D 10	3307060.0000	0.686012D 12	1360.000000	638427.00000	236.291
E01_72	88	252.181818	530.302051	0.281220D 06	22192.0000	0.244662D 08	1.000000	3354.00000	210.286
E02_72	88	1737.363636	4078.411242	0.166334D 08	152888.0000	0.144711D 10	19.000000	25208.00000	234.747
E03_72	88	15267.215909	32906.921140	0.108287D 10	1343515.0000	0.942093D 11	365.000000	238566.00000	215.540
E04_72	88	2116.875000	5755.715236	0.331283D 08	186285.0000	0.288216D 10	59.000000	42307.00000	271.897
E05_72	88	9189.659091	23120.683325	0.534566D 09	808690.0000	0.465072D 11	187.000000	167919.00000	251.595
E06_72	88	1836.977273	5562.158768	0.309376D 08	161654.0000	0.269157D 10	40.000000	38560.00000	302.789
E07_72	88	5901.295455	15722.840115	0.247208D 09	519314.0000	0.215071D 11	61.000000	113418.00000	266.430
E08_72	88	1172.443182	3414.433229	0.116584D 08	103175.0000	0.101428D 10	41.000000	29460.00000	291.224
TOT_74	88	43584.818182	100926.068496	0.101861D 11	3835464.0000	0.886188D 12	1818.000000	729088.00000	231.562
E01_74	88	270.500000	546.232509	0.298370D 06	23804.0000	0.259582D 08	1.000000	3534.00000	201.934
E02_74	88	1814.238636	4094.858582	0.167679D 08	159653.0000	0.145880D 10	30.000000	27120.00000	225.707
E03_74	88	16060.965909	33883.799296	0.114311D 10	1413365.0000	0.998857D 11	441.000000	246229.00000	210.970
E04_74	88	2180.272727	5781.859242	0.334299D 08	191864.0000	0.290840D 10	66.000000	42752.00000	265.193
E05_74	88	9830.761364	24506.162563	0.600552D 09	865107.0000	0.522480D 11	206.000000	176717.00000	249.280
E06_74	88	1943.215909	5780.786449	0.334175D 08	171003.0000	0.290732D 10	42.000000	39358.00000	297.486
E07_74	88	6502.681818	17247.625898	0.297481D 09	572236.0000	0.258808D 11	72.000000	124388.00000	265.239
E08_74	88	4866.647727	10496.981106	0.110185D 09	428265.0000	0.958605D 10	322.000000	70503.00000	215.690
POP_72	88	121845.454545	232327.076670	0.539759D 11	10722400.0000	0.469590D 13	10000.000000	1670100.00000	190.674
POP_73	88	122089.772727	230214.916101	0.529989D 11	10743900.0000	0.461090D 13	10200.000000	1645300.00000	188.562
DEL_C8	88	3694.204545	8006.898631	0.641104D 08	325090.0000	0.557761D 10	277.000000	60002.00000	216.742
DEL_TOT	88	2310.386364	4397.262645	0.193359D 08	203314.0000	0.168222D 10	2.000000	30659.00000	190.326
DEL_POP	88	244.318182	3277.224013	0.107402D 08	21500.0000	0.934397D 09	-24800.000000	9600.00000	1341.375
DEL_01	88	18.318182	110.785964	0.122735D 05	1612.0000	0.106780D 07	-260.000000	664.00000	604.787
DEL_02	88	76.875000	391.947006	0.153622D 06	6765.0000	0.133652D 08	-2085.000000	1912.00000	509.850
DEL_03	88	793.750000	1511.995258	0.228613D 07	69850.0000	0.198893D 09	-4243.000000	8281.00000	190.488
DEL_04	88	63.397727	157.070636	0.246712D 05	5579.0000	0.214639D 07	-718.000000	628.00000	247.754
DEL_05	88	641.102273	1493.844812	0.223157D 07	56417.0000	0.194147D 09	-98.000000	9013.00000	233.012
DEL_06	88	106.238636	266.662212	0.711087D 05	9349.0000	0.618646D 07	-35.000000	2083.00000	251.003
DEL_07	88	601.386364	1539.232735	0.236924D 07	52922.0000	0.206124D 09	-5.000000	10970.00000	255.947

136

TABLE 5

COUNTY RANKS FOR EACH CHANGE VARIABLE

S	NAME	DEL_POP	DEL_TOT	DEL_01	DEL_02	DEL_03	DEL_04	DEL_05	DEL_06	DEL_07	SUM
1	ADAMS	74.0	8.0	40.0	4.0	31	68.0	10.0	6.0	2.0	243.0
2	ALLEN	7.5	77.0	55.5	53.0	82	78.0	65.0	71.0	73.0	562.0
3	ASHLAND	38.5	39.0	63.0	60.0	54	50.5	18.0	2.0	26.0	351.0
4	ASHTABULA	10.0	75.0	70.0	42.5	80	42.5	70.5	49.0	66.0	505.5
5	ATHENS	5.0	13.0	20.0	12.0	14	39.5	23.0	80.0	14.0	220.5
6	AUGLAIZE	64.0	51.0	20.0	54.5	57	8.0	54.5	37.5	50.0	396.5
7	BELMONT	12.0	19.0	86.0	28.0	3	55.0	36.0	50.5	57.0	346.5
8	BROWN	46.0	15.0	40.0	17.0	28	5.0	25.0	5.0	20.0	201.0
9	BUTLER	86.0	78.0	51.0	77.0	76	85.0	78.0	83.0	69.0	683.0
10	CARROLL	69.5	26.0	76.0	29.0	26	26.0	42.0	69.0	9.0	372.5
11	CHAMPAIGN	64.0	17.0	40.0	35.0	21	24.0	37.0	21.0	12.0	271.0
12	CLARK	10.0	32.0	29.0	7.0	10	80.0	19.0	74.0	70.5	331.5
13	CLERMONT	83.5	69.0	40.0	85.0	49	69.0	64.0	56.0	54.0	569.5
14	CLINTON	46.0	44.0	40.0	66.0	61	30.0	34.0	7.0	3.0	331.0
15	COLUMBIANA	64.0	74.0	81.0	63.0	79	42.5	72.0	60.0	44.0	579.5
16	COSHOCTON	32.5	30.0	84.0	3.0	48	62.0	50.0	28.0	42.0	379.5
17	CRAWFORD	38.5	62.0	40.0	30.0	75	45.5	46.0	40.0	39.0	416.0
18	CUYAHOGA	1.0	88.0	7.5	88.0	87	84.0	87.0	86.0	88.0	616.5
19	DARKE	64.0	41.0	58.5	70.0	42	57.0	21.5	27.0	61.0	442.0
20	DEFIANCE	28.5	36.0	40.0	36.0	37	15.0	47.0	58.0	47.0	344.5
21	DELAWARE	82.0	58.0	70.0	19.0	56	61.0	73.0	67.5	45.0	531.5
22	ERIE	38.5	63.0	24.0	59.0	44	9.0	74.0	62.0	76.0	449.5
23	FAIRFIELD	79.5	56.5	30.0	67.0	55	45.5	59.0	50.5	64.0	507.0
24	FAYETTE	19.0	22.0	40.0	41.0	33	11.0	31.0	12.0	18.5	227.5
25	FRANKLIN	79.5	86.0	13.0	1.0	77	87.0	88.0	88.0	87.0	606.5
26	FULTON	28.5	38.0	40.0	74.0	32	63.5	52.0	42.0	23.5	393.5
27	GALLIA	38.5	70.0	14.0	87.0	8	3.0	60.0	46.0	43.0	369.5
28	GEAUGA	78.0	56.5	51.0	13.0	68	53.0	45.0	17.5	60.0	442.0
29	GREENE	64.0	31.0	58.5	21.5	45	7.0	7.5	21.0	49.0	304.5
30	GUERNSEY	28.5	59.0	1.0	61.0	73	19.0	54.5	3.5	63.0	362.5
31	HAMILTON	3.0	87.0	40.0	2.0	88	1.0	86.0	87.0	86.0	480.0
32	HANCOCK	50.0	54.0	6.0	10.0	59	71.5	67.0	43.5	62.0	423.0
33	HARDIN	46.0	46.0	11.0	72.0	64	28.0	3.0	31.0	22.0	323.0
34	HARRISON	38.5	5.0	60.5	31.0	13	21.0	21.5	35.0	1.0	226.5
35	HENRY	38.5	35.0	40.0	44.0	29	70.0	43.0	25.5	37.0	362.0
36	HIGHLAND	57.0	4.0	28.0	8.5	9	15.0	35.0	64.5	5.5	226.5
37	HOCKING	17.0	7.0	74.0	25.5	4	42.5	28.0	31.0	25.0	254.0
38	HOLMES	38.5	29.0	78.0	49.0	36	32.5	26.0	33.5	17.0	339.5
39	HURON	57.0	53.0	40.0	47.0	63	37.5	56.0	57.0	32.0	442.5
40	JACKSON	69.5	42.0	18.0	14.0	65	39.5	17.0	14.5	10.0	289.5
41	JEFFERSON	14.0	50.0	3.0	81.0	34	81.0	51.0	8.5	48.0	370.5
42	KNOX	32.5	18.0	65.5	52.0	15	73.0	30.0	29.0	41.0	356.0
43	LAKE	83.5	84.0	12.0	46.0	84	71.5	83.0	75.0	80.0	619.0
44	LAWRENCE	14.0	20.0	10.0	51.0	17	66.0	38.0	37.5	40.0	293.5
45	LICKING	28.5	60.0	7.5	57.0	46	50.5	75.0	64.5	72.0	461.0
46	LOGAN	53.5	47.0	26.0	54.5	60	59.5	33.0	43.5	29.5	406.5
47	LORAIN	85.0	83.0	60.5	82.0	85	79.0	80.0	73.0	79.0	706.5
48	LUCAS	7.5	81.0	72.0	86.0	43	77.0	79.0	82.0	85.0	612.5
49	MADISON	46.0	21.0	57.0	40.0	25	31.0	44.0	31.0	15.0	310.0
50	MAHONING	14.0	80.0	63.0	49.0	83	52.0	70.5	78.0	81.0	570.5
51	MARION	23.0	66.0	26.0	56.0	69	49.0	62.0	48.0	67.0	466.0
52	MEDINA	87.0	73.0	22.0	76.0	67	47.0	77.0	77.0	59.0	585.0
53	MEIGS	59.5	45.0	87.0	24.0	19	83.0	4.0	17.5	16.0	355.0
54	MERCER	59.5	48.0	40.0	65.0	53	56.0	48.0	67.5	33.0	470.0
55	MIAMI	64.0	76.0	26.0	45.0	81	4.0	61.0	70.0	68.0	495.0
56	MONROE	53.5	25	88.0	25.5	7	19.0	2.0	14.5	4.0	238.5
57	MONTGOMERY	2.0	65	17.0	5.0	1	2.0	85.0	85.0	83.0	345.0
58	MORGAN	19.0	2	83.0	15.0	11	25.0	5.0	8.5	7.0	175.5
59	MORROW	53.5	12	54.0	38.0	6	23.0	27.0	72.0	27.5	313.0
60	MUSKINGUM	23.0	49	82.0	42.5	35	82.0	58.0	25.5	46.0	443.0
61	NOBLE	28.5	14	20.0	27.0	30	6.0	6.0	12.0	21.0	164.5
62	OTTAWA	69.5	28	75.0	83.0	5	67.0	20.0	40.0	36.0	423.5
63	PAULDING	38.5	6	40.0	16.0	12	36.0	7.5	17.5	38.0	211.5
64	PERRY	77.0	9	77.0	21.5	20	15.0	11.0	12.0	18.5	261.0
65	PICKAWAY	50.0	24	40.0	11.0	38	12.5	39.0	17.5	29.5	261.5
66	PIKE	23.0	11	40.0	19.0	23	28.0	13.0	40.0	8.0	205.0
67	PORTAGE	76.0	72	70.0	23.0	70	63.5	66.0	23.5	75.0	539.0
68	PREBLE	16.0	27	40.0	37.0	39	12.5	32.0	52.5	13.0	269.0
69	PUTNAM	19.0	16	53.0	39.0	22	17.0	29.0	36.0	11.0	242.0
70	RICHLAND	23.0	1	15.5	78.0	2	75.0	53.0	79.0	52.0	378.5
71	ROSS	28.5	64	5.0	80.0	58	59.5	68.0	52.5	58.0	473.5
72	SANDUSKY	53.5	23	2.0	34.0	24	34.5	14.0	46.0	53.0	284.0
73	SCIOTO	10.0	43	40.0	19.0	40	54.0	57.0	54.0	55.0	372.0
74	SENECA	57.0	52	79.0	6.0	71	32.5	15.0	61.0	56.0	429.5
75	SHELBY	74.0	61	55.5	68.0	72	37.5	49.0	55.0	35.0	507.0
76	STARK	88.0	85	85.0	84.0	86	86.0	84.0	84.0	82.0	764.0
77	SUMMIT	4.0	82	65.5	73.0	79	76.0	81.0	1.0	84.0	544.5
78	TRUMBULL	6.0	79	80.0	79.0	62	88.0	82.0	81.0	78.0	635.0
79	TUSCARAWAS	74.0	67	67.5	71.0	66	65.0	69.0	59.0	65.0	603.5
80	UNION	64.0	33	4.0	69.0	50	22.0	16.0	46.0	23.5	327.5
81	VAN WERT	46.0	40	40.0	49.0	47	19.0	40.0	63.0	34.0	378.0
82	VINTON	38.5	3	15.5	32.5	18	34.5	9.0	10.0	5.5	166.5
83	WARREN	69.5	55	23.0	32.5	41	58.0	63.0	3.5	77.0	422.5
84	WASHINGTON	50.0	37	9.0	75.0	51	42.5	1.0	23.5	51.0	340.0
85	WAYNE	72.0	71	67.5	62.0	74	74.0	24.0	66.0	70.5	581.0
86	WILLIAMS	38.5	10	51.0	8.5	16	28.0	41.0	21.0	27.5	241.5
87	WOOD	81.0	68	73.0	64.0	27	48.0	76.0	76.0	74.0	587.0
88	WYANDOT	23.0	34	63.0	58.0	52	10.0	12.0	33.5	31.0	316.5

TABLE 6

COUNTIES RANKED BY 1972 POPULATION

OBS	NAME	SUM *
1	VINTON	2.0
2	NOBLE	1.0
3	MORGAN	3.0
4	MONROE	11.0
5	HARRISON	8.5
6	PAULDING	6.0
7	PIKE	5.0
8	MEIGS	37.0
9	ADAMS	14.0
10	HOCKING	15.0
11	CARROLL	44.0
12	WYANDOT	26.0
13	MORROW	25.0
14	HOLMES	31.0
15	UNION	28.0
16	FAYETTE	10.0
17	GALLIA	41.0
18	PERRY	16.0
19	JACKSON	21.0
20	HENRY	39.0
21	BROWN	4.0
22	MADISON	24.0
23	HIGHLAND	8.5
24	VAN WERT	45.0
25	CHAMPAIGN	19.0
26	CLINTON	29.0
27	HARDIN	27.0
28	PUTNAM	13.0
29	WILLIAMS	12.0
30	COSHOCTON	47.0
31	FULTON	48.0
32	PREBLE	18.0
33	LOGAN	50.0
34	MERCER	63.0
35	DEFIANCE	33.0
36	OTTAWA	54.0
37	SHELBY	68.5
38	GUERNSEY	40.0
39	AUGLAIZE	49.0
40	PICKAWAY	17.0
41	KNOX	38.0
42	ASHLAND	36.0
43	DELAWARE	70.0
44	DARKE	56.5
45	HURON	58.0
46	CRAWFORD	51.0
47	ATHENS	7.0
48	WASHINGTON	32.0
49	LAWRENCE	22.0
50	SENECA	55.0
51	ROSS	64.0
52	HANCOCK	53.0
53	SANDUSKY	20.0
54	GEAUGA	56.5
55	MARION	62.0
56	FAIRFIELD	68.5
57	ERIE	60.0
58	TUSCARAWAS	80.0
59	SCIOTO	43.0
60	MUSKINGUM	59.0
61	BELMONT	35.0
62	WARREN	52.0
63	MEDINA	78.0
64	MIAMI	66.0
65	WAYNE	77.0
66	WOOD	79.0
67	JEFFERSON	42.0
68	CLERMONT	74.0
69	ASHTABULA	67.0
70	ALLEN	73.0
71	COLUMBIANA	76.0
72	LICKING	61.0
73	GREENE	23.0
74	PORTAGE	71.0
75	RICHLAND	46.0
76	CLARK	30.0
77	LAKE	84.0
78	BUTLER	86.0
79	TRUMBULL	85.0
80	LORAIN	87.0
81	MAHONING	75.0
82	STARK	88.0
83	LUCAS	82.0
84	SUMMIT	72.0
85	MONTGOMERY	34.0
86	FRANKLIN	81.0
87	HAMILTON	65.0
88	CUYAHOGA	83.0

*Counties are sorted by their 1972 population (column 1, OBS and NAME). They are then ranked by the sum of total change in population and all employment categories given in Table 5 (SUM).

TABLE 7

COUNTIES RANKED BY 1972 EMPLOYMENT

OBS	NAME	SUM *
1	VINTON	2.0
2	NOBLE	1.0
3	MEIGS	37.0
4	CARROLL	44.0
5	PAULDING	6.0
6	ADAMS	14.0
7	MORGAN	3.0
8	MORROW	25.0
9	BROWN	4.0
10	PIKE	5.0
11	PERRY	16.0
12	HOLMES	31.0
13	MADISON	24.0
14	MONROE	11.0
15	PREBLE	18.0
16	HOCKING	15.0
17	JACKSON	21.0
18	WYANDOT	26.0
19	PUTNAM	13.0
20	FAYETTE	10.0
21	HARRISON	8.5
22	CHAMPAIGN	19.0
23	HIGHLAND	8.5
24	HARDIN	27.0
25	UNION	28.0
26	GALLIA	41.0
27	CLINTON	29.0
28	HENRY	39.0
29	VAN WERT	45.0
30	LOGAN	50.0
31	OTTAWA	54.0
32	LAWRENCE	22.0
33	CLERMONT	74.0
34	PICKAWAY	17.0
35	DARKE	56.5
36	MERCER	63.0
37	FULTON	48.0
38	KNOX	38.0
39	COSHOCTON	47.0
40	AUGLAIZE	49.0
41	DELAWARE	70.0
42	GEAUGA	56.5
43	GUERNSEY	40.0
44	WILLIAMS	12.0
45	WARREN	52.0
46	ATHENS	7.0
47	ROSS	64.0
48	DEFIANCE	33.0
49	ASHLAND	36.0
50	SHELBY	68.5
51	HURON	58.0
52	WASHINGTON	32.0
53	CRAWFORD	51.0
54	SCIOTO	43.0
55	SANDUSKY	20.0
56	BELMONT	35.0
57	MEDINA	78.0
58	GREENE	23.0
59	HANCOCK	53.0
60	FAIRFIELD	68.5
61	SENECA	55.0
62	TUSCARAWAS	80.0
63	MARION	62.0
64	MUSKINGUM	59.0
65	COLUMBIANA	76.0
66	MIAMI	66.0
67	JEFFERSON	42.0
68	ASHTABULA	67.0
69	WOOD	79.0
70	PORTAGE	71.0
71	WAYNE	77.0
72	ERIE	60.0
73	LICKING	61.0
74	ALLEN	73.0
75	CLARK	30.0
76	LAKE	84.0
77	RICHLAND	46.0
78	BUTLER	86.0
79	LORAIN	87.0
80	TRUMBULL	85.0
81	MAHONING	75.0
82	STARK	88.0
83	LUCAS	82.0
84	SUMMIT	72.0
85	MONTGOMERY	34.0
86	FRANKLIN	81.0
87	HAMILTON	65.0
88	CUYAHOGA	93.0

*Counties are sorted by their 1972 employment (column 1, OBS and NAME). They are then ranked by the sum of total change in population and all employment categories given in Table 5 (SUM).

urban counties. Based on this analysis, a sample of counties most representative of economic, population, and use change in Ohio can be drawn for the modeling effort.

One other data question which must be discussed is a method of projection for poplation and employment which can be used as inputs for future use of the models developed in this study. One model which has been used extensively for this purpose is the DEMOS model developed by Battelle.

The model projects population and employment by county to 1985 with a 1970 base year. The question remains whether this model is accurate enough to utilize as the basis for projections of land use change made with models developed in this accuracy is to test DEMOS projections for 1972 and 1974 against currently available data for these years.

DEMOS projections have been made for all Ohio counties for these years in order to make this test. The test was made as a part of Phase II of this project and is given as Appendix A of the Phase II report.

General Approach to Land Conversion Modeling

Given a data base with several types of land use, economic, population, and tax data, the approach which will be taken to define models of land use change in Ohio must be delineated. We may first define a set of land use change or tax change categories:

Y_i = land, category i; i = 1, 2, 3...n.

These categories are defined by the nature of land use or tax information and may include residential, commercial, industrial, etc.

We may also define a set of employment categories:

X_j = employment, category j; j - 1,2, 3...m.

Employment is used as the economic indicator because it appears to be the most readily available and complete data set.

Changes in land use (or tax base) Y is then given as:

$Y_i = f_i \ (Y_k \neq i, \ X_{\forall j})$

In this equation, changes in land use for category are explained by the endogenous variables Y not equal to i (all other land use changes) and all changes in employment.

Not only will competition among uses and employment affect land use and tax structure changes, but also the absolute size of a county's employment, population, and land base will affect land conversion. They, we can define function 2:

Where:

$Y_i - f_2 \ (Y_k \neq i, \ X_{\forall j}, \ Z, \ A)$

Z = total employment or population in the base year

A= total area of the county

Equation of this type can be defined using regression analysis. The advantage of this technique is the output of measures of reliability and statistical accuracy for all resultant equations.

In the sections below, results for all models are given.

Model 1 - Tax Board Data, 36 Counties

Regression equations were defined for the 36 counties with parcel information for 1967 and 1972. The variables list is given by Table 8. Tables 9 to 11 show the intercorrelations amongst the variables used in the analysis. Here it can be seen that many variables heavily intercorrelated. Thus, several variables were summed into combined indicators to eliminate redundancy. This was done for household related employment (Tables 12 to 14).

Tables 15 to 22 show the results of the regression analysis. In each table, the dependent variable is given on the top of the page in capitol letters. Then, the regression coefficients are given for the indicated variables and years. The F statistic of significance is given in parentheses after each beta coefficient. At the bottom of each section of the table are given the R^2 statistic and the adjusted R^2 , R^2 (a). This indicates the amount of variance explained by each regression equation. The constant in each equation (c) is also given in the table. A better understanding of how to interpret each table is given on page 32, Explanation of Tables.

Model 2 - Tax Board Data, 88 Counties

The second set of regressions were run with the assessed value of land and total assessed value for the 88 counties in Ohio, 1967, 1972, and 1967-1972.

TABLE 8

LIST OF VARIABLES

VAR001: COUNTY INDEX NUMBER

VAR002: POPULATION 1967

VAR003: POPULATION 1972

VAR004: TOTAL EMPLOYMENT 1967 (EXCLUDED GOVERNMENT)

VAR005: MINING EMPLOYMENT 1967

VAR006: CONSTRUCTION EMPLOYMENT 1967

VAR007: MANUFACTURING EMPLOYMENT 1967

VAR008: TRANSPORTATION UTILITIES EMPLOYMENT 1967

VAR009: WHOLESALE AND RETAIL EMPLOYMENT 1967

VAR010: FINANCE INSURANCE EMPLOYMENT 1967

VAR011: SERVICE EMPLOYMENT 1967

VAR012: TOTAL EMPLOYMENT 1972 (EXCLUDED GOVERNMENT)

VAR013: MINING EMPLOYMENT 1972

VAR014: CONSTRUCTION EMPLOYMENT 1972

VAR015: MANUFACTURING EMPLOYMENT 1972

VAR016: TRANSPORTATION UTILITIES EMPLOYMENT 1972

VAR017: WHOLESALE AND RETAIL EMPLOYMENT 1972

VAR018: FINANCE INSURANCE EMPLOYMENT 1972

VAR019: SERVICES EMPLOYMENT 1972

IND020: ASSESSED VALUE AGRICULTURAL LAND 1967

IND021: ASSESSED VALUE INDUSTRIAL LAND 1967

IND022: ASSESSED VALUE COMMERCIAL LAND 1967

IND023: ASSESSED VALUE RESIDENTIAL LAND 1967

IND024: ASSESSED VALUE ALL TAXABLE LAND 1967

IND025: ASSESSED VALUE AGRICULTURAL LAND 1972

IND026: ASSESSED VALUE INDUSTRIAL LAND 1972

IND027: ASSESSED VALUE COMMERCIAL LAND 1972

IND028: ASSESSED VALUE RESIDENTIAL LAND 1972

IND029: ASSESSED VALUE ALL TAXABLE LAND 1972

IND030: ASSESSED VALUE AGRICULTURE BUILDINGS 1967

IND031: ASSESSED VALUE INDUSTRIAL BUILDINGS 1967

IND032: ASSESSED VALUE COMMERCIAL BUILDINGS 1967

IND033: ASSESSED VALUE RESIDENTIAL BUILDIGNS 1967

IND034: ASSESSED VALUE ALL TAXABLE BUILDINGS 1967

IND035: ASSESSED VALUE AGRICULTURE BUILDINGS 1972

IND036: ASSESSED VALUE INDUSTRIAL BUILDINGS 1972

IND037: ASSESSED VALUE COMMERCIAL BUILDINGS 1972

IND038: ASSESSED VALUE RESIDENTIAL BUILDINGS 1972

IND039: ASSESSED VALUE ALL TAXABLE BUILDINGS 1972

IND060: TOTAL AG ASSESSED VALUE 1967

IND061: TOTAL IND ASSESSED VALUE 1967

IND062: TOTAL COMM ASSESSED VALUE 1967

IND063: TOTAL RES ASSESSED VALUE 1967

IND065: TOTAL AG ASSESSED VALUE 1972

IND066: TOTAL IND ASSESSED VALUE 1972

IND067: TOTAL COMM ASSESSED VALUE 1972

IND068: TOTAL RES ASSESSED VALUE 1972

V002: DELTA POPULATION 1967-72

V004: DELTA TOTAL EMPLOYMENT (EXCLUDED GOVERNMENT) 1967-72

V005: DELTA MINE EMPLOYMENT 1967-72

V006: DELTA CONSTRUCTION EMPLOYMENT 1967-72

V007: DELTA MANUFACTURING EMPLOYMENT 1967-72

TABLE 8 (Continued)

V008: DELTA TRANSPORTATION EMPLOYMENT 1967-72

V009: DELTA WHOLESALE-RETAIL EMPLOYMENT 1967-72

V010: DELTA FINANCE-INSURANCE EMPLOYMENT 1967-72

V011: DELTA SERVICES EMPLOYMENT 1967-72

V012: DELTA HOUSEHOLD EMPLOYMENT 1967-72

DAR012: HOUSEHOLD EMPLOYMENT 1967

DAR013: HOUSEHOLD EMPLOYMENT 1972

I020: DELTA AG LAND VALUE 1967-72

I021: DELTA IND LAND ASSESSED VALUE 1967-72

I022: DELTA COMM LAND ASSESSED VALUE 1967-72

I023: DELTA RES LAND ASSESSED VALUE 1967-72

I024: DELTA TOTAL LAND ASSESSED VALUE 1967-72

I029: DELTA RES AND COMM LAND A-VALUE 1967-72

I030: DELTA AG BUILDINGS ASSESSED VALUE 1967-72

I031: DELTA IND BUILDINGS ASSESSED VALUE 1967-72

I032: DELTA COMM BUILDINGS ASSESSED VALUE 1967-72

I033: DELTA RES BUILDINGS ASSESSED VALUE 1967-72

I034 DELTA TOTAL BUILDINGS ASSESSED VALUE 1967-72

I060: DELTA TOTAL AG ASSESSED VALUE 1967-72

I061: DELTA TOTAL IND ASSESSED VALUE 1967-72

I062: DELTA TOTAL COMM ASSESSED VALUE 1967-72

I063: DELTA TOTAL RES ASSESSED VALUE 1967-72

I069: DELTA RES AND COMM TOTAL A-VALUE 1967-72

Changes in Urban Land Assessed Values 1967-72

Table 9 - Correlation Coefficients Among Change Variables 1967-72

	I021	I022	I023
I021	1.00000	.89452	.88701
I022		1.00000	.74707
I023			1.00000

Table 10 - Correlation Coefficients of Change Variables with State Variables 1967

	VAR002	VAR004	VAR007	VAR008	VAR009	VAR10	VAR011
I021	.90904	.92279	.91420	.91786	.91407	.92421	.91996
I022	.84145	.83399	.80151	.82698	.84109	.88617	.86053
I023	.95904	.96597	.95885	.96343	.96550	.93449	.95986

Table11 - Correlation Coefficients of Change Variables with Change Variables 1967-72

	V002	V004	V007	V008	V009	V010	V011
I021	-.66230	.71660	-.81784	.71611	.81608	.78282	.89767
I022	-.31793	.87747	-.61213	.86607	.90241	.86760	.87179
I023	-.73841	.70094	-.91562	.68426	.82666	.84528	.94328

Cases: 88
All Coefficients Significance = 0.001

Aggregation of household oriented employment

Table 12 Correlation Coefficients State Variables 1967

	VAR002	VAR008	VAR009	VAR010	VAR011
VAR002	1.00000	0.98379	0.99333	0.96761	0.98997
VAR008		1.00000	0.99373	0.97374	0.99052
VAR009			1.00000	0.98129	0.99833
VAR010				1.00000	0.98779
VAR011					1.00000

Table 13 Correlation Coefficients State Variables 1972

	VAR003	VAR016	VAR017	VAR018	VAR019
VAR003	1.00000	0.9826	0.9938	0.9677	0.9919
VAR016		1.0000	0.9921	0.9710	0.9899
VAR017			1.0000	0.9825	0.9989
VAR018				1.0000	0.9865
VAR019					1.0000

Table 14 Correlation Coefficients Change Variables 1967-72

	V008	V009	V010	V011
V008	1.00000	0.92942	0.89463	0.85984
V009		1.00000	0.96902	0.95325
V010			1.00000	0.94359
V011				1.00000

Cases: 88
All Coefficients Significance = 0.001

Explanation of Regression-Model Tables (Tables 15-38)

As indicated earlier, equations for the land conversion models can be defined by selected variables using regression analysis. Using Table 23 as an example, we can explain in more detail how one interprets each of the dependent variable, "assessed value of all taxable land for 1967 and 1972". The dependent variable is always labelled under the table number of each of the regression models.

The regression-model table contains the results of ofur statistical regression analyses. The first analysis is shown under the column heading "1967" which indicates the year of the dependent variable. The independent variable for this analysis are shown on the left-hand margin. For Table 23 "1967", the independent variables are VAR002 (1967 population), VAR007 (1967 manufacturing employment) and DAR012 (1967 household employment). The first set of numbers (i.e., 311.87, 616.22, 706.34) represents the weight of each independent variable in the regression equation. The associated number in parentheses for each independent variable is the F-statistic which indicates the statiscal significance of each independent variable in the regression equation. The regression constant, $C(10^3)$, is shown under the independent variables. Thus the regression equation for 1967 in Table 23 is

$$Y_{IND029} = 3901.23\text{X}10^3 + 311.87\ (\text{VAR002})$$
$$+\ 616.22\ (\text{VAR007}) + 706.34\ (\text{DAR012})$$

where:

Y_{IND029} = assessed value all taxable land,

VAR002 = total population 1967,

VAR007 = manufacturing employment 1967,

DAR012 = household employment 1967.

When this equation is applied to the 88 Ohio counties, 99.158% of the statistical variance in the model is explained, as indicated by the R^2 value.

This example illustrates a highly predictive model. By adjusting the R^2 for the sample size and the number of independent variables, 99.138% of the statistical variance is explained, as indicated by the R^2 (a) value.

The results of this regression analysis (i.e. 1967 for Table 23) implies that if data exists for counties in Ohio in 1967 on total population and the two employment types (manufacturing and household), one can predict greater than 99% of the time 1967 assessed value for all taxable land in the counties. Thus, the implication of the model is potential prediction of assessed value for all taxable land based on projected population and employment data.

Similarly, the regression equations for the three additional models represented in Table 23 can be constructed. These additional models are (1) a simple 1967 model with total population as the only independent variables, (2) a model for 1972 assessed value of all taxable land with three independent variables, and (3) a simple model for 1972 with total population as the only independent variable.

The interpretative procedure, as described above, may be applied similarly to the other regression-model tables presented in this report.

TABLE 15

RESIDENTIAL PARCELS*

	1967	1972	
VAR002	.38724 (72.54)	.39467 (101.91)	VAR003
DAR012	-1.02500 (12.52)	- .72120 (15.86)	DAR013
C	2252.39	2339.35	
R^2	.99043	.99274	
R^2 (a)	.99015	.99253	
VAR002	.22692 (2540.76	.23963 (3131.02)	VAR003
C	7519.91	7374.84	
R^2	.98679	.98926	
Mean	37473.	38769	

*Sample of 36 counties

150

TABLE 16

COMMERCIAL PARCELS*

	1967	1972	
VAR002	.02634 (15.20)	.02087 (13.63)	VAR003
DAR012	-.04967 (1.33)	.01722 (0.43)	DAR013
C	313.18	340.80	
R^2	.96905	.98563	
R^2(a)	.96814	.98521	

	1967	1972	
DAR012	.11748 (718.12	.11351 (1640.24	DAR013
C	1197.63	1035.94	
R^2	95479	.97969	
Mean	3019.	3440.	

*Sample of e6 counties.

TABLE 17

INDUSTRIAL PARCELS*

	1967	1972	
VAR002	.00408 (3.24)	.00305 (1.11)	VAR003
VAR007	- .01259 (.80	--.00258 (.02)	VAR015
C	164.60	183.54	
R^2	.73970	.74826	
R^2	.73205	.74086	
VAR007	.01260 (84.93)	.01833 (96.66)	VAR015
C	251.88	189.56	
R^2	.71412	.73979	
Mean	477	539.	

*Sample of 36 counties

TABLE 18

DELTA RESIDENTIAL PARCELS 1967-72

V002	.22972 (29.69)
VAR002	.01170 (22.01)
C	22.08444

R^2	.47444
R^2(a)	.45899
Mean	1295.53

VAR002 99000

V002	.12603 (1.42)
VAR002	-.01052 (0.43)
C	1027.917068

R^2	.0579
R^2(a)	.02171
Mean	769.10

TABLE 19

DELTA COMMERCIAL PARCELS 1967-72

DAR012	.03506	(283.86)
C	-47.10469	
R^2	.89304	
Mean	420.91	

VAR002 99000

V012	.07869	(.50)
C	-124.70376	
R^2	.01898	
Mean	-18.21	

TABLE 20

DELTA INDUSTRIAL PARCELS 1967-72

V007	-.02060 (20.74)
C	35.72305
R^2	.37891
Mean	62.52

VAR002 99000

VAR004	.01635 (5.63)
C	-94.11369
R^2	.17791
Mean	35.07

TABLE 21

DELTA PUBLIC UTILITIES PARCELS 1967-72

V002	-.08740	(5.42)
V004	-.69876	(3.43)
V009	3.04437	(12.69)
VAR004	-.020829	(17.97)
V007	-.065627	(2.99)
V011	1.00701	(2.59)
C	838.81868	

R^2	.53520
R^2(a)	.45773
Mean	

VAR002 99000

V007	-2.01662	(3.70)
V002	-.19752	(6.94)
VAR002	-.05081	(3.73)
V011	-.02032	(0.00)
V005	-2.24002	(1.95)
V004	.80717	(.82)
C	1602.05829	

R^2	.78343
R^2(a)	.72155
Mean	-313.46

TABLE 22

DELTA RESIDENTIAL AND COMMERCIAL PARCELS 1967-72

V012	.32012	(33.44)
V002	.20393	(21.77)
C	166.62244	
R^2	.50895	
$R^2(a)$	.49451	
Mean	1716.44	

VAR002 99000

V002	.13494	(1.59)
DAR012	-.19329	
C	1012.97130	
R^2	.07582	
R^2	.04028	
Mean	750.89	

Tables 23 to 38 give the results for these models. The tables are constructed in the same fashion as those for Model 1 above.

One can see that each of these models is very strong, explaining a minimun of almost 90% of the variance. At this stage, it is not possible to discuss in detail the reasons why certain variables have entered the equations.

Several additional tests of the data and equations need to be made in Phase II in order to define a final set of tax base models. What is indicated at this stage is the possibility of contructing very strong explanatory models of the changes in Ohio's tax base.

TABLE 23

ASSESSED VALUE ALL TAXABLE LAND

	1967		1972		
VAR002	311.87	(42.82)	241.18	(4.57)	VAR003
VAR007	616.22	(10.07)	1396.09	(10.44)	VAR015
DAR012	706.34	(7.95)	1818.68	(20.02)	DAR013
	3910.23		5926.65		
R^2	.99158		.98487		
R^2(a)	.99138		.98452		

VAR002	514.66	8238.20	823.90	(4216.44)	VAR003
C(10^3)	1544.06		-9123.26		
R^2	.98967		.98001		

Mean Value	61322779.	91265538.
Max	954572500.	
Min	4251867.	4162957.

TABLE 24

ASSESSED VALUE RESIDENTIAL LAND

	1967		1972		
VAR002	281.07	(134.62)	155.63	(3.89)	VAR003
VAR007	321.24	(10.59)	1432.29	(22.46)	VAR015
DAR012	-134.46	(1.11)	794.20	(7.80)	DAR013
$C(10^3)$	-6615.45		-8587.46		
R^2	.99396		.98181		
$R^2(a)$	.99382		.98138		
VAR002	309.48	(12453.19)	524.62	(3487.89)	VAR003
$C(10^3)$	-6809.64		-16554.28		
R^2	.99314		.97594		
Mean Value	30993644		47368497		
Max	534298875		952651250		
Min	593000		669640		

TABLE 25

ASSESSED VALUE COMMERCIAL LAND

	1967		1972		
DAR012	761.74	(16.16)	963.34	(105.78)	DAR013
VAR002	31.09	(.74)	43.34	(2.78)	VAR003
VAR007	83.76	(.32)	-155.56	(2.44)	VAR015
$C(10^3)$	-2769.09		3014.81		
R^2	.95306		.98951		
$R^2(a)$	.95196		.98926		
DAR012	1042.21	(1693.71)	1063.58	(7808.85)	DAR013
$C(10^3)$	-1432.76		2016.91		
R^2	.95186		.98911		
Mean Value	12652290.		18238812		
Max	327851750		393033937		
Min	94400		94400.		

TABLE 26

ASSESSED VALUE INDUSTRIAL LAND

	1967		1972		
DAR012	390.66	(50.40	460.04	(31.37)	DAR013
VAR007	262.71	(37.93)	505.33	(33.52)	VAR015
VAR002	-56.50	(29.13)	-97.21		VAR003
$C(10^3)$	599.97		566.59		
R^2	.94917		.92639		
$R^2(a)$	.94797		.92466		

	1967		1972		
$C(10^3)$			510.13	(759.30)	VAR015
			-2590.49		
R^2			.89826		

	1967	1972
Mean Value	3142700.	5197847.
Max	91787312.	13082312.
Min	5130.	34340.

162

TABLE 27

DELTA RESIDENTIAL LAND ASSESSED VALUE 1967-72

(10^3)

VAR002	.16464	(492.08)
V002	-.895555	(40.00)
I020	1.28365	(12.00)
IND020	-.48910	(5.97)
C	-3761.07	
R^2	.94862	
$R^2(a)$	.94363	

Mean	16374851.
Min	
Max	

TABLE 28

DELTA RESIDENTIAL LAND ASSESSED VALUE 1967-72

(10^3)

V004	-1.66589	(53.50)
VAR002	.25494	(777.06)
I020	.88711	(7.30)
IND020	-.41250	(4.70)
C	-4934.11	

R^2	.95370
$R^2(a)$	.95204

Mean	16374851.
Min	
Max	

TABLE 29

DELTA INDUSTRIAL LAND ASSESSED VALUE 1967-72

(10^3)

V007	.46125	(13.39)
VAR007	.05887	(5.58)
IND021	.57523	(35.43)
I020	-.06069	(1.14)
C	-89.95	

R^2	.89605
R^2(a)	.89234

Mean	2055146
Min	
Max	

TABLE 30

DELTA COMMERCIAL LAND ASSESSED VALUE 1967-72

(10^3)

V012	1.37676	(53.21)
DAR012	.69014	(33.59)
IND002	-.63634	(110.99)
VAR002	-.01738	(1.04)
C	-1179.52	
R^2	.92153	
R^2(a)	.91873	

Mean	5586520
Min	
Max	

166

TABLE 31

DELTA RESIDENTIAL & COMMERCIAL LAND ASSESSED VALUE 1967-72

(10^3)

DAR012	1.31460	(23.57)
V004	-.60024	(5.41)
I020	.78633	(4.12)
IND020	-.26005	(1.63)
INd022	.12720	(0.60)
IND023	.17469	(3.60)
C	-161.73	

R^2	.91776
$R^2(a)$	.97004

Mean	21961372
Min	
Max	

TABLE 32

TOTAL RESIDENTIAL ASSESSED VALUE

	1967		1972		
VAR002	800.91	(47.00)	1045.48	(137.11)	VAR003
DAR012	1796.16	(8.55)	-319.99	(0.988)	DAR013
VAR007	793.12		2119.45	(38.38)	VAR015
$C(10^3)$	-10247.39		-1487.72		
R^2	.99067		.99596		
$R^2(a)$	.99045		.99587		

	1967		1972		
VAR002	1198.32	(7986.63)	1272.21	(14314.98)	VAR003
$C(10^3)$	-21942.23		-16219.37		
R^2	.98935		.99395		

	1967	1972
Mean Value	155396375	186115312
Max		
Min	3793700	4432020

TABLE 33

TOTAL COMMERCIAL ASSESSED VALUE

	1967		1972		
VAR007	3650.52	(40.78)	-140.67	(0.382)	VAR015
VAR002	-448.47	(10.21)	198.84	(11.21)	VAR003
DAR012	1822.81	(6.11)	1397.15	(42.58)	DAR013
$C(10^3)$	1991.86		7264.12		
R^2	.89306		.98750		
$R^2(a)$	.89054		.98720		
			2222.99	(5743.31)	DAR013
$C(10^3)$			-911.74		
R^2			.98525		
Mean Value	42365719		59645348		
Max					
Min	638860		648710		

TABLE 34

TOTAL INDUSTRIAL ASSESSED VALUE

	1967		1972		
VAR007	1452.89	(42.16)	1709.25	(72.48)	VAR015
DAR012	1126.43	(15.23)	475.99	(6.34)	DAR013
VAR002	-165.37	(9.06)	-107.92	(4.24)	VAR003
$C(10^3)$	4032.30		2605.32		
R^2	.94837		.96093		
$R^2(a)$	.94715		.96001		

VAR007	1504.07	(1323.89)	1663.31	(1960.11)	VAR015
$C(10^3)$	1757.08		-778.20		
R^2	.93900		.95797		

Mean Value	25230578.	29808551.
Max	507840250.	518877812.
Min	88340.	285720.

TABLE 35

DELTA TOTAL RESIDENTIAL ASSESSED VALUE 1967-72

(10^3)

VAR002	.21989	(256.09)
I060	3.45933	(65.29)
IND060	-.58045	(6.60)
V002	-.62063	
C	154168	
R^2	.87569	
$R^2(a)$	.87129	

Mean	30718944.
Min	
Max	

TABLE 36

DELTA TOTAL COMMERCIAL ASSESSED VALUE 1967-72

(10^3)

V012	12.61351	(77.63)
V002	1.31763	(10.64)
I060	-1.68601	(34.28)
DAR012	1.87392	(12.13)
VAR002	-.19966	(12.18)
IND060	.40007	(7.01)
C	-2737.17	

R^2	.93974
$R^2(a)$	.93607

Mean	17279623.
Min	
Max	

172

TABLE 37

DELTA TOTAL INDUSTRIAL ASSESSED VALUE 1967-72

(10^3)

VAR002	-.02170	(2.63)
V002	.48332	(52.43)
VAR007	.52989	(26.53)
V007	1.12970	(18.17)
IND060	-.08291	(3.00)
I060	.13780	(2.55)
C	918.80	
R^2	.76963	
$R^2(a)$	.75559	

Mean	4577979.
Min	
Max	

TABLE 38

DELTA RESIDENTIAL & COMMERCIAL TOTAL ASSESSED VALUE 1967-72

(10^3)

V012	1.72848	(1.75)
V002	3.41777	(72.99)
VAR002	.40056	(24.53)
I060	1.85202	(20.88)
IND060	-.44851	(4.22)
C	8810.51	

R^2	.95629
R^2(a)	.95419

Mean	47998566.
Min	
Max	

177

FOOTNOTES

1. R. Ellefson, P.H. Swain and J.R. Wray <u>Urban Land Use Mapping by Machine Processing of ERTS-1 Multispectral Data: A San Francisco Bay Example</u> (West Lafayette, Indiana: The Laboratory for Applications of Remote Sensing, Purdue University) LARS Information Note 101573, p. 2A-9.

2. Armond T. Joyce "Land Use and Mapping," in S.C. Freden et al. (ed.), <u>Third Earth Resources Technology Satellite Symposium</u>. <u>Volume 2</u>, (Springfield, Va.: National Technical Information Service #N75-10560, 1974), p. 138-146.

3. Ibid.

4. James R. Wray "Cartographic Aspects of an Operational System for Detecting Urban Change by Remote Sensing." <u>EROS Reprint #157</u>, (Washington, D.C.: U.S. Geological Survey,Geographic Applications Program).

5. Ellefson, Swain, and Wray. "Urban Land Use Mapping...", p. 2A-9.

6. Paul L. Vegas "Extracting Land Information from the Earth Resources Technology Satellite Data by Coventional Interpretation Methods," <u>NASA Technical Note</u>, NASA TN D-7730 (Springfield,Va.: NTIS #N7428896, July, 1974) p. 7.

7. Ibid., p. 8.

8. Ohio-Kentucky-Indiana Regional Council of Governments, <u>Land Use Inventory</u> by Drainage Area, Interim Report III (Cincinnati, Ohio: OKI, August, 1975) p. 8.

FOOTNOTES (Continued)

9. Joseph W. Wiedel and Richard Kleckner, Using Remote Sensor Data for Land Use Mapping and Inventory: A User Guide, USGS Interagency Report USGS-253 (Springfield, Va.: NTIS #PB-242 813, July, 1974.)

10. Richard Ellefson, Leonard Gaydoes, and James R. Wray "Computer Aided Mapping of Land Use ERTS Multispectral Scanner Data, "First Pan American Congress on Photogrammetry, Photointerpretation, and Geodosy. (Mexico City, Mexico, July 1974); Richard Ellefson, Leonard Gaydoes, Phillip Swain and James R. Wray "New Techniques in Mapping Urban Land Use and Monitoring Change for Selected U.S. Metropolitan Areas: An Experiment Employing Computer-Assisted Analysis of ERTS-1 MSS Data." Presented at International Society of Photogrammetry Symposium, Commission VII, Banff, Alberta, Canada, October, 1974

11. Ellefson, Gaydoes, Swain, and Wray, "New Techniques...".

12. Ellefson, Swain, and Wray. "Urban Land-Use Mapping...".

13. Bendix Aerospace Systems Division, Computer Mapping of LANDSAT Data for Environmental Applications (Ann Arbor, Michigan: Bendix Corporation, November, 1975) p.8.

14. James R. Anderson, Ernest E. Hardy, and John T. Roach, A Land-Use Classification System for Use with Remote Sensor Data (Washington, D.C.: U.S. Geological Survey Circular 671, 1972.)

CHAPTER III-II

PHASE II SUMMARY

Agricultural Sector Models

Phase I of the Ohio Land Allocation Model established a number of cross-sectional statistical models of tax assessment and tax parcel changes in the residential, commercial, and industrial land use sectors. Each of these equations utilized the assessed value or number of parcels in each land category as the dependent variables and employment and population as the independent variables. Equations were derived which explained tax base in a static sense (i.e. 1967 residential assessed value for 88 Ohio counties as a function of 1967 employment and population) and in a dynamic sense (change in tax assessed value 1967 to 1972 as a function of change in employment and population during the same period).

Similar models for the agricultural sector did not work as well as those for the other land use sectors. This is because population and employment variables do not incorporate the factors important for agricultural production. For this reason, a data base relating to agricultural production was compiled. Data on cash receipts to Ohio farmers were available from the Ohio Agricultural Research and Development Center.[1] Data on the acreage harvested for each crop type were extracted from Ohio Agricultural Statistics while data on the number of farms, average acreage and land in farms by county for 1964-1974 were made available by the Ohio Crop Reporting Service.[2] Table 39 lists the variables which were used in the analysis of the agricultural sector.

Table 39

LIST OF VARIABLES, AGRICULTURAL SECTOR TAX BASE EQUATIONS

V67001 - Cash Receipts 000's $ Total Livestock 1967

V67002 - Cash Receipts 000's $ Dairy 1967

V67003 - Cash Receipts 000's $ Cattle 1967

V67004 - Cash Receipts 000's $ Hogs 1967

V67005 - Cash Receipts 000's $ Poultry 1967

V67006 - Cash Receipts 000's $ Sheep 1967

V67007 - Cash Receipts 000's $ Other 1967

V67008 - Cash Receipts 000's $ Total Crops 1967

V67009 - Cash Receipts 000's $ Corn 1967

V67010 - Cash Receipts 000's $ Soybean 1967

V67011 - Cash Receipts 000's $ Wheat 1967

V67012 - Cash Receipts 000's $ Oats and Hay 1967

V67013 - Cash Receipts 000's $ Greenhouse 1967

V67014 - Cash Receipts 000's $ Vegs. 1967

V67015 - Cash Receipts 000's $ Other Crops 1967

V67016 - Acres Harvest Corn For Grain 1967

V67017 - Acres Harvest Soybeans for Beans 1967

V67018 - Acres Harvest All Wheat 1967

V67019 - Acres Harvest Oats for Grain 1967

V67020 - Acres Harvest All Hay 1967

V67021 - All Cattle and Calves (Head) 1967

V67022 - All Hogs and Pigs (Head) 1967

V67023 - All Sheep (Head) 1967

V67024 - All Milk Cows (Head) 1967

S67 Acres - Total Acres Harvested 1967

LF 67 - Land in Farms 000's Acres 1967

NF 67 - Number of Farms 1967

LIST OF VARIABLES, AGRICULTURAL SECTOR TAX BASE EQUATIONS

AA 67 - Average Acreage 1967

INDO 20 - Assessed Value Agricultural Land 1967

INDO 60 - Total Assessed Value Agricultural Land 1967

V72001 - Cach Receipts 000's $ Total Livestock 1972

V72002 - Cash Receipts 000's $ Dairy 1972

V72003 - Cash Receipts 000's $ Cattle 1972

V72004 - Cash Receipts 000's $ Hogs 1972

V72005 - Cash Receipts 000's $Poultry 1972

V72006 - Cash Receipts 000's $ Sheep 1972

V72007 - Cash Receipts 000's $ Other 1972

V72008 - Cash Receipts 000's $ Total Crops 1972

V72009 - Cash Receipts 000's $ Corn 1972

V72010 - Cash Receipts 000's $ Soybean 1972

V72011 - Cash Receipts 000's $ Wheat 1972

V72012 - Cash Receipts 000's $Oats and Hay 1972

V72013 - Cash Receipts 000's $ Greenhouse 1972

V72014 - Cash Receipts 000's $ Vegs. 1972

V72015 - Cash Receipts 000's $ Other Crops 1972

V72016 - Acres Harvest Corn For Grain 1972

V72017 - Acres Harvest Soybeans For Beans 1972

V72018 - Acres Harvest All Wheat 1972

V72019 - Acres Harvest Oats For Grain 1972

V72020 - Acres Harvest All Hay 1972

V72021 - All Cattle and Calves (Head) 1972

V72022 - All Hogs and Pigs (Head) 1972

V72023 - All Sheep 1972 (Head)

V72024 - All Milk Cows 1972 (Head)

Table 39 (cont'd)

LIST OF VARIABLES, AGRICULTURAL SECTOR TAX BASE EQUATIONS

S72 Acres	- Total Acres Harvested 1972
LF 72	- Land in Farms 000's Acres 1972
NF 72	- Number of Farms 1972
AA 72	- Average Acreage 1972
INDO 25	- Assessed Value Agricultural Land 1972
INDO 65	- Total Assessed Value Agricultural Land 1972
SMSA 67	- Counties in an SMSA, 1967
SMSA 72	- Counties in an SMSA, 1972
AVLIV67	- Mean of Cash Receipts Livestock, 1962-1967, 000's $
AVCRP67	- Mean of Cash Receipts Crops, 1962-1967, 000's $
AVLIV72	- Mean of Cash Receipts Livestock, 1968-1972, 000's $
AVCRP 72	- Mean of Cash Receipts Crops, 1968-1972, 000's $
I021	- Delta ind. Land Assessed Value, 1967-1972
I022	- Delta comm. Land Assessed Value, 1967-1972
I023	- Delta res. Land Assessed Value, 1967-1972
I020	- Delta ag. Land Assessed Value, 1967-1972
I060	- Delta & Total ag. Assessed Value, 1967-1972
CHGCRP	- AVCRP72 minus AVCRP67
CHGLIV	- AVLIV72 minus AVLIV67

Data Analysis

The first step in the project was to analyze the data base using descriptive statistics. The results of this analysis give an overview of the general trends in Ohio's agricultural sector.

Land use in Ohio is diversified. Of the state's 26.2 million acres of land, 11 per cent was dedicated to urban and built up areas in 1970; 65.3 per cent was farmland; and 23.7 per cent was categorized as other land not in farms.[3] As evidenced from this data, the agricultural sector is clearly a dominant land use within the State of Ohio.

Changes in the state's agriculture indicate that the number of farms and land in farms is decreasing, while average acreage is increasing. Although Ohio is following the national trend, data indicate that the state is not doing so in as radical and rapid a pace as the national average. For example, the average national farm size in 1973 was about 385 acres [4] while Ohio's average farm size for the same year was almost 149 acres. From 1964-1974 the average acreage on Ohio farms increased by 7.2 acres. The 1969 Census of Agriculture reports that 96.2 per cent of all farms in Ohio are less than 499 acres. Small farms, 1 to 99 acres constitute 46.5 per cent of this total.[5] This data would seem to indicate that although Ohio is slowly following the national trend, the state remains dominated by relatively small farms and small farmers as opposed to large corporate farming operations that are prevalent in other states. Tables 40 and 41 illustrate these data.

Table 40. Ohio 1964, 1969, 1974

Land in Farms 000's			Average Acres per Farm			Number of Farms 000's		
1964	1969	1974	1964	1969	1974	1964	1969	1974
18,145	17,700	17,400	141.6	148.1	148.8	131	120	117

Source: Ohio Crop Reporting Service

Table 41. United States

	Average Acres per Farm	
1964	1969	1974
332	369	384

Source: U.S. Department of Agriculture, Statistical Reporting Service, 1973.

The assessed value of farms in Ohio has increased 23.1 per cent from 1964 to 1969. Crops increased 15.4 per cent and livestock, poultry, and related products increased 29 per cent.[6] Data for 1967, one of the years that will be used in this study, show that livestock products are 57.5 per-cent of the total while crops constitute 42.5 per cent of the total agricultural production in Ohio.[7] In 1972, the other year relevant to this study, livestock products constituted 52.8 per cent and crops proved to be 47.2 per cent of the total.[8] Table 42 illustrates livestock and major crops by type.

Table 42

	1967	1972
Total Livestock	57.5%	52.8%
Cattle & Calves	14.8%	16.6%
Hogs	14.5%	13.4%
Dairy Products	18.8%	16.9%
Total Crops	42.5%	47.2%
Corn	11.4%	11.9%
Soybeans	12.3%	18.5%
Wheat	5.3%	3.7%

The next step in the analysis was to delineate the interrelationship among the variables. This was critical in that strong correlations among independent variables in the regression equations (multicollinearity) can yield erroneous results.

Several sets of variables were found to be correlated. First, the analysis showed the relationship among the cash receipts variables and the acres harvested variables to be collinear. This means that in almost all instances the cash receipts from a specific crop and the acres harvested from that same crop will correlate significantly. Table 43 illustrates the correlation coefficients for cash receipts and acres harvested. For example, cash receipts for wheat (V72011) and acres harvested for wheat (V72018) show a correlation coefficient of .90505. Similarly, cash receipts for soybeans (V72010) and acres harvested for soybeans (V72017) correlate at .99385. As a result of this collinearity the regression statements which included both cash receipts and acreage for the same crop would give biased results. It is for this reason that the regressions use only the cash receipts for each crop and livestock variable. The decision to eliminate the acres harvested variables was based on the fact that cash receipts proved to be a stronger explanation of assessed value.

Collinearity was also a factor in determining the relationship among major crop types. This is shown in Table 44. The analysis showed that certain types of crops were intimately related. One explanation for this phenomenon is that certain crops are grown together or alternately in a rotation. Some crops require the same type of storage, soil, or involve similar transportation costs. Soybeans (V72010) and wheat (V72011) correlate significantly.

Table 43

RELATIONSHIPS AMONG CASH RECEIPTS AND ACREAGE

HARVESTED VARIABLES

CORRELATION COEFFICIENTS*

	V67018	V67019	V72003	V72016	V72017	V72018
V67009	.90000	.55295				
V67010	.85954	.55772				
V67011	.98199	.63133				
V67012	.65113	.80253				
V67016						
V72009				.89848	.87421	.80287
V72010				.84860	.99385	.84102
V72011				.86372	.93204	.90505
V72016			.67246			
V72021			.82175			

*Underlined coefficients indicate variables which are collinear and should not be used in the same regression equation.

Table 44

RELATIONSHIPS AMONG MAJOR CROP TYPES

CORRELATION COEFFICIENTS

	V67009	V67011	V72009	V72011
V67010	.89185	.89100	0.89816	0.93534
V67011	.91392	1.00000	0.88707	0.95602
V72010	------	------	.90784	.94601
V72011	------	------	.90587	1.00000

Corn (V72009) is collinear with soybeans (V72010) and with wheat (V72011). Based on the theory of transportation costs one would not expect vegetables (V72014) to correlate highly with wheat or corn. This is, in fact, the case. It may also be posited that vegetables are intensive while wheat and corn are extensive crops, hence they would not be highly related in terms of where they are grown.

Given adjustments in the input data to avoid the use of collinear variables, analysis was carried out using linear regression. The results are summarized in the next section.

Results of Agricultural Sector Models

The goal of the regression analysis was to create predictive models of the tax base related to production in the agricultural sector and the conversion of land to urban uses. In each equation, one of the agricultural tax base variables (e.g. IND060 - total agricultural assessed value, 1967), is the dependent variable and production variables or assessment variables in other categories (residential, commercial, industrial) are the independent or explanatory variables.

Tables 45 to 50 illustrate the results of these analyses. All the tables are similarly organized. Using Table 45 as an example, one can see how to interpret the results. This table represents the models for assessed value of agricultural land as given by the title. Results of two equations are shown in this table - one for 1967 as shown in the left half, and one for 1972 as shown in the right half. On the left margin are the names of all the independent variables for the 1967 equation. The first numbers following this are the B coefficients, the numbers by which one multiplies to arrive at the predicted value for the dependent variable. In parentheses after this number

are the t ratios which show the statistical significance of each of the B values. At the bottom of the table are shown the constant for each equation and the coefficient of determination (R^2). The R^2 and R^2(a) (adjusted) values show the proportion of the variance explained by the equation.

Going back to Table 45, we can illustrate how one can translate into a predictive equation. Using the 1967 equation:

$$\begin{aligned} \text{IND025} = {} & .921\ (\text{V67004}) + 3.789\ (\text{V67007}) + 1.718\ (\text{V67009}) \\ & + 1.008\ (\text{V67010}) + 10.493\ (\text{V67012}) + 1.177\ (\text{V67013}) \\ & + 2927.345\ (\text{SMSA67}) + 3361.156 \end{aligned}$$

If one wishes to predict the assessed value of agricultural land for any county in Ohio using this equation, one need only have the production figures for each of the crop types in the equation and know whether or not the county was in an SMSA. One can interpret each of the tables in a similar fashion. How these equations will be translated into models for use on the state computer system is discussed further in the final chapter of this report.

Several interesting trends are shown by these regression equations. Tables 45 and 46 show that a strong relationship exists between agricultural production and assessed value in both 1967 and 1972. The R^2 (a) values for these equations range from .683 to .809. Certain products are shown to be more important in Ohio agriculture. These include hogs, corn, soybeans, greenhouse, and other crops categories.

Viewing the coefficients in these equations, it appears that there were changes in the importance of particular crops between the two years. Thus, the b coefficient for soybeans in 1967 is 1.008 while it is 1.808 in 1972. It may not be true, however, that these two single years are representative of long term trends in Ohio agriculture. For this reason data on the

Table 45

Assessed Value Agricultural Land*

	1967		1972		
Indep.Variables	B	t ratio	B	t ratio	Indep.Var.
V67004	.921	(3.51)	1.524	(3.95)	V72003
V67007	3.789	(1.44)	29.400	(4.55)	V72007
V67009	1.718	(3.14)	1.808	(8.96)	V72010
V67010	1.008	(1.86)	1.539	(3.03)	V72013
V67012	10.493	(3.97)	5003.686	(3.41)	SMSA72
V67013	1.177	(3.35)			
SMSA67	2927.345	(3.03)			
C (constant)	3361.156		2952.364		C
	.826		.705		R^2
	.809		.691		R^2(a)

	1967		1972
Mean	14545.002		19894.229
Δ Mean		5349.227	

* All coefficients are significant at the .001 level except

V67007 (.2)
V67010 (.1)

Table 46

Total Agricultural Assessed Value*

Indep. Variables	1967 B	1967 t ratio	1972 B	1972 t ratio	Indep. Var.
V67007	19.228	(4.21)	1.102	(2.79)	V72002
V67009	3.508	(7.62)	1.873	(3.11)	V72003
V67012	18.474	(4.14)	32.738	(3.30)	V72007
V67013	1.572	(2.50)	1.890	(5.36)	V72010
			7.146	(1.30)	V72012
			2.205	(3.15)	V72013
SMSA67	3827.692	(2.21)	6387.938	(3.07)	SMSA72
C	8781.813		5405.612		C
R^2	.729		.705		R^2
R^2(a)	.716		.683		R^2(a)
Mean	24880.412		30561.794		Mean
Δ Mean		5681.38			

*All coefficients are significant at the .01 level.

Except V67013 (.02)
SMSA67 (.05)
V72012 (.2)

Table 47

ASSESSED VALUE AGRICULTURAL LAND*

	1967		1972		
Indep.Var.	B	t ratio	B	t ratio	Indep. Var.
V67001	.490	(5.21)	.531	(4.30)	V72001
V67008	1.175	(11.30)	.910	(7.78)	V72008
C	3488.230		6535.432		C
R^2	.707		.562		R^2
R^2(a)	.704		.557		R^2(a)
AVLIV67	.632	(5.89)	.648	(4.68)	AVLIV72
AVCRP67	1.243	(10.10)	1.272	(8.19)	AVCRP72
C	3120.179		5537.328		
[illegible]	.695		.589		
R^2(a)	.691		.582		
AVLIV67	.678	(6.54)	.701	(5.35)	AVLIV72
AVCRP67	1.181	(9.89)	1.179	(7.94)	AVCRP72
SMSA67	2986.172	(3.01)	5322.154	(3.48)	SMSA72
C	2191.150		3340.624		
R^2	.725		.639		
R^2(a)	.719		.630		
Mean	14545.002		19894.229		
Δ Mean		5349.227			

*All coefficients are significant at the.01 level.

Table 48 *

TOTAL AGRICULTURAL ASSESSED VALUE

Indep.Var.	1967 B	t ratio	1972 B	t ratio	Indep.Var.
V67001	.949	(6.08)	.975	(5.81)	V72001
V67008	1.443	(8.17)	.987	(6.15)	V72008
C	8552.664		12179.983		C
R^2	.638		.546		R^2
R^2 (a)	.634		.541		R^2 (a)
AVLIV67	1.157	(6.22)	1.164	(6.24)	AVLIV72
AVCRP67	1.530	(7.63)	1.404	(6.71)	AVCRP72
C	7965.607		10755.133		C
	.637		.580		R^2
R^2 (a)	.633		.575		R^2 (a)
AVLIV67	1.256		1.234	(6.97)	AVLIV72
AVCRP67	1.396		1.281	(6.39)	AVCRP72
SMSA67	6423.951		7016.750	(3.40)	SMSA72
C	5967.050		7858.989		C
R^2	.699		.631		R^2
R^2 (a)	.692		.623		R^2 (a)
Mean	24880.412		30561.794		
Δ Mean		5681.38			

*All coefficients are significant at the.001 level.

Table 49 *

DELTA AGRICULTURAL LAND VALUE (1967-72)

Indep. Var.	B	t ratio
CHGLIV	.607	(2.87)
CHGCRP	.891	(3.72)
I021	-1.357	(8.07)
I022	.317	(6.52)
I023	.089	(5.70)
SMSA72	2330.842	(3.08)
C	1817.123	
R^2	.561	
R^2 (a)	.534	

Mean (10^3) 5349.227

*All coefficients are significant at the .001 level.
Except CHGLIV (.01)

192

Table 50 *

DELTA TOTAL AGRICULTURAL ASSESSED VALUE (1967-72)

Indep. Var.	B	t ratio
CHGLIV	.792	(3.05)
CHGCRP	.664	(2.26)
I021	-2.072	(10.03)
I022	.294	(4.92)
I023	.165	(8.61)
SMSA72	2299.777	(2.47)
C	2603.019	
R^2	.639	
R^2 (a)	.617	

Mean (10^3) 5681.383

*All coefficients are significant at the .01 level except

CHGCRP (.05)
SMSA72 (.02)

C-3

annual cash receipts for crops and livestock were collected for 1962 through 1972. Thus, instead of employing the single year cash receipts variable, a six and five year average (1962-1967, 1968-1972) were input into the regression equations. The results are shown in Tables 47 and 48. Here, one can compare the results using the simple totals for one year (V67001, V67008) to the results using the averages (AVLIV67, AVCRP67). Not only do the b coefficients change but also they become stable over time. The coefficient for AVLIV67 is .632 and for AVLIV72 .648 - not significantly different. What this means is that changes in agricultural assessed value from 1967-1972 are accounted for almost entirely by the dummy variables for urbanization - SMSA67, SMSA72. In other words, competition from urban land uses in SMSA counties was bidding up the price and, therefore, the assessed value of agricultural land. To the best of our knowledge, this is the first time that this trend has been demonstrated quantitatively with a predictive equation.

The final set of predictive equations are those for change (delta) in assessed value 1967-72. Here it was found that changes in agricultural production do not explain changes in assessed value. This is an expected result since we can assume that overall agricultural production in Ohio is probably near its peak and is only slightly affected by short term fluctuations in the produce market. We would then expect that it is the competition by other land uses for agricultural land which would better explain changes in assessed value. This is demonstrated by Tables 49 and 50. Here, one can see that changes in production combined with changes in the other land categories give a strong estimate of agricultural assessed value.

There are actually several trends which seem to be measured by these equations. First, there is the effect of a slight increase in production. Second, there is the effect of urban land bidding up the prices of agricultural land. This is shown by the SMSA, commercial land, and residential land

variables. Third, there is the effect of direct consumption of agricultural land on the urban fringe. This effect seems to be most highly correlated with the industrial land category and is why this coefficient is negative. Finally, it must be pointed out that changes in agricultural building assessed value are almost negligible. The mean change in land value is $5349.227 x 10^3 and in total value is $5681.383 x 10^3 leaving only a change of $332.16 x 10^3. This is because tax assessments between 1967 and 1972 were made exclusively on the basis of market value of land. The value of agricultural buildings for urban uses is negligible. Thus, the strongest equation for delta total agricultural assessed value is generated by using the same variables as those used for the land assessed value equation. This is shown in Table 50.

Converting Tax Base Data to Land Use Information

One set of models which was produced during Phase I of this study is that for tax parcels. These models predict the number of tax parcels in each category of land use given projections of population and employment. Data on tax parcels are readily available and would, therefore, be an excellent, continuing source of information. What is needed then is an assessment of whether or not these data can be converted to actual land acreages. One of the major accomplishments during Phase II of the Ohio Land Allocation Model study is just such an assessment. The general approach, methodology, results, and conclusions are explained in this chapter.

Land Acreage from Parcel Data

In order to derive the acreage from data on parcels, one would need to know the size of each parcel. Alternatively, one may derive a frequency or probability distribution of parcel sizes in each county for each land category. This distribution can then be multiplied by the number of parcels in each category in order to get the acreage. Table 51 illustrates how one would calculate the probable acreage of residential land in a hypothetical county based on a sample of sizes of parcels in that county.

Table 51

HYPOTHETICAL DISTRIBUTION OF RESIDENTIAL PARCEL SIZES

SHOWING THE CALCULATION OF ACREAGE

Parcel Size (Acres)	Number in Sample	Frequency	Acreage*
.1	100	.10	250.0
.25	500	.50	3125.0
.50	200	.20	2500.0
.75	100	.10	1875.0
1.00	50	.05	1250.0
1.50	20	.02	750.0
2.5	10	.01	625.0
7.5	10	.01	1875.0
10.0	5	.005	1250.0
11.0	5	.005	1375.0
Total	1000	1.000	14875.0

*Actual total number of residential parcels = 25000 using 0.1 acre size as example

25000 x .10 frequency = 2500 x .1 acres = 250 acres

Sampling Parcel Data

The purpose of the survey undertaken was to gain information about the size of tax parcels in each of the four major land uses and to determine whether or not reliable profiles of parcel sizes could be established. This was done by taking a two per cent random sample of the tax parcels in three central Ohio counties: Pickaway (Circleville), Delaware (Delaware), and Licking (Newark). The land use type and acreage for each parcel selected were coded for keypunching and the samples were analyzed using the Statistical Package for the Social Sciences (SPSS).

The source of the parcel information was the public record of appraisal compiled by each county's auditor for 1975. Each parcel record contained the owner's name, an identifying parcel number, a legal description of the parcel, the assessed value of the land and buildings, and in some cases the acreage or dimensions of the parcel. These records are organized in the following way:

Pickaway County

First level - by township or incorporated area
Second level - by school district
Third level - alphabetically by owner's name
Thirteen parcels per page

Delaware County

Same manner as Pickaway, but 35-50 records per page

Licking County (two complete listings)

Alphabetically by owner's name, thirteen records per page

First level - by township or incorporated area
Second level - by school district
Third level - by land use type
Fourth level - alphabetically by owner's name
Sixteen records per page

A random number table with values ranging from 1 to 52 was used to select the parcels to be recorded. In Pickaway and Licking Counties the random number between 1 and 52 identified one record in a four page block. In Delaware County, only values between 1 and 40 were used and each number identified a record for a single page. When a parcel was selected, the land use and acreage of the parcel was recorded with the following exceptions:

1) If the parcel had no acreage recorded, its subdivision name and lot number were noted and the dimensions of the lot taken from the plat record, converted to acres and recorded.

2) If the legal description contained the dimensions of the parcel, e.g. 150' x 250', this information was noted and converted to acres.

3) If the legal description did not identify a subdivision name or contain the dimensions of the parcel, the parcel was rejected and another random number and parcel selected. A deed search is necessary to identify the acreage of such a parcel.

Because industrial and commercial parcels make up a very small portion of the parcels within a county, very few such parcels were selected in the random sampling process. This deficiency was corrected by selecting a township book in an area containing industrial and commercial land and recording all such parcels which showed acreage in the sample until a minimum of fifty parcels were recorded.

The coded information was keypunched and SPSS was used to calculate the frequency distributions and simple statistics for each sub-sample, in both grouped and ungrouped form. Table 52 displays the results of the ungrouped analysis and the sample sizes for each land use and county.

The frequency distributions obtained from the random sample were compared using the Smirnov test. This test was chosen because it does not assume a normally distributed population, and the populations from which the samples

were drawn are not normally distributed. The test statistic, called the D value, is the largest difference between the cumulative frequencies for each grouping of the two samples being tested. The samples were grouped as shown in Table 53. If the D value is larger than the critical value, the two samples are significantly different. The samples were compared within land use types, the results are displayed in Table 54. The significantly different samples were the residential sample for Licking County compared to both Delaware and Pickaway Counties, and the commercial samples for Delaware and Licking Counties. The difference probably resulted from the more urbanized nature of Licking County. Platted parcels are more numerous in urbanized areas and are generally smaller than non-platted parcels.

The three samples taken do not allow generalization of the results to the entire state. However, they do indicate that profiles of different types of counties (urban, rural, metropolitan) could be developed with a sample of 10-15 counties. Sampling this many counties could require as many as 1000 man-hours. However, as more auditors' records become computerized, such a sample could become feasible. If reliable profiles could be developed it would allow translation of the existing number of parcels data to acreage, providing much useful information about land use and land use change. In this way, projections made using the tax parcel models can be directly translated into land use projections.

The results of this type of analysis could then be used as a continuing and consistent check on the accuracy of macro level land use totals produced by LANDSAT. Future work with the tax models and continued use of LANDSAT could generate a data base in the future which directly linked land use change as measured by LANDSAT with the changes in tax base in Ohio Counties.

Table 52

PARCEL SIZE SURVEY SIMPLE STATISTICS (UNGROUPED DATA)

	Pickaway	Delaware	Licking	All Counties
Agricultural Parcels				
N	106	156	235	497
Mean	49.3	40.4	43.4	43.7
Median	32.0	38.1	32.8	34.0
Variance	2791.3	1038.8	1523.9	1644.6
Skewness	1.449	1.668	1.252	1.557
Industrial Parcels				
N	53	73	81	207
Mean	11.3	9.0	23.6	15.3
Median	3.0	3.1	6.0	4.2
Variance	413.0	173.3	1560.1	163.5
Skewness	3.394	2.038	2.285	6.929
Commercial Parcels				
N	52	80	176	308
Mean	3.0	3.5	4.8	4.2
Median	0.8	0.8	0.9	0.8
Variance	139.3	49.9	222.6	163.5
Skewness	6.628	3.429	6.457	6.929
Residential Parcels				
N	240	530	754	1524
Mean	1.0	1.4	0.8	1.0
Median	0.3	0.3	0.2	0.25
Variance	4.2	8.5	3.6	5.5
Skewness	4.404	3.643	6.514	4.783
All Parcels				
N	451	839	1246	2536
*Estimated Total Parcels	18,000	29,000	52,000	99,000
Sample Size	2.5%	2.9%	2.4%	2.6%

*State Board of Tax Appeals

TABLE 53

Group	Land Use Type: Agricultural	Industrial	Commercial	Residential
1	.1-.9	.1-.9	.1-.2	.1
2	1.0-9.9	1.0-4.9	.3-.4	.2
3	10.0-29.9	5.0-9.9	.5-.6	.3
4	30.0-49.9	10.0-14.9	.7-.8	.4
5	50.0-69.9	15.0-24.9	.9-1.0	.5
6	70.0-89.9	25.0-49.9	1.0-2.9	.6
7	90.0-109.9	50.0-74.9	3.0-4.9	.7
8	110.0-129.9	75.0-99.9	5.0-6.9	.8
9	130.0-159.9	100.0-149.9	7.0-9.9	.9
10	160.0+	150.0+	10.0-49.9	1.0-1.4
11			50.0-99.9	1.5-1.9
12			100.0+	2.0-2.9
13				3.0-4.9
14				5.0+

Inclusive Group Limits in Acres

Table 54

SUMMARY OF SMIRNOV TESTS

Samples Tested	LAND USE TYPES							
	AGRICULTURAL		INDUSTRIAL		COMMERCIAL		RESIDENTIAL	
Licking-Delaware	N(1) 235	N(2) 156	N(1) 81	N(2) 73	N(1) 176	N(2) 80	N(1) 754	N(2) 530
Critical Values								
.05 Level	.140		.219		.184		.077	
.01 Level	.168		.263		.220		.092	
D Values	.091		.184		.216*		.158*	
Pickaway-Delaware	N(1) 106	N(2) 156	N(1) 53	N(2) 73	N(1) 52	N(2) 80	N(1) 240	N(2) 530
Critical Values								
.05 Level	.171		.245		.242		.106	
.01 Level	.205		.294		.290		.127	
D values	.139		.184		.135		.094	
Licking-Pickaway	N(1) 235	N(2) 106	N(1) 81	N(2) 53	N(1) 176	N(2) 52	N(1) 754	N(2) 240
Critical Values								
.05 Level	.159		.240		.215		.101	
.01 Level	.191		.288		.257		.121	
D Values	.102		.061		.081		.215*	

*Significantly different samples

$$\text{Critical Value at .05 Level} = 1.36\sqrt{\frac{N(1) + N(2)}{N(1) \times N(2)}}$$

$$\text{Critical Value at .01 Level} = 1.63\sqrt{\frac{N(1) + N(2)}{N(1) \times N(2)}}$$

D Values = Maximum (Cumulative Frequency(1,i) - Cumulative Frequency(2,i))

i = 1 to number of groups in distribution

Land Conversion in Franklin County

Establishing a Test for LANDSAT Data

LANDSAT offers the opportunity to provide computer compatible land use information at frequent intervals. Thus, land use changes as measured by LANDSAT can be linked with changes in population, employment, and other socioeconomic characteristics to produce empirical models of land use change. This is the underlying goal of the modeling effort in the State of Ohio. In pursuing this goal, a number of technical problems have arisen which require further exploration before a set of final models can be produced. This section summarizes the work using aerial photography for Franklin County, Ohio, which will be utilized in performing a test of the accuracy of LANDSAT interpretations.

Land Use Modeling and LANDSAT

In order to create a predictive land use model for counties in Ohio, a land use data base is required which is both extensive and accurate. LANDSAT provides a unique opportunity for such modeling because it is the most extensive, most consistent data base available. Unfortunately, a number of technical problems arise in converting from LANDSAT imagery to land use categories. These problems leave a potential for large errors in the final land use classifications.[9] Such errors would be unacceptable for the purpose of land use modeling, i.e. relating land use changes to socioeconomic changes. Thus, the first step in analyzing LANDSAT must be to identify the nature and degree of these errors, and if possible, to derive correction

204

factors which might be applied prior to the use of these data in a model.

The potential errors associated with LANDSAT have been subdivided into two major components. Those errors associated with the misalignment of pixels for two different LANDSAT scenes are referred to as Error 1. This error results from the possibility of $\pm$ one pixel misalignment in ground orientation as a result of the rescanning readjustment, and reclassification of the original, distorted data pixels.[10] The second type of error (Error 2) results from the misclassification of land cover due to the similarities in spectral signatures of different land uses. To date, the nature and extent of these errors have not been quantified. This is the first task of LANDSAT data analysis in Ohio.

Quantifying LANDSAT Errors

In order to quantify the misclassification errors associated with LANDSAT, a number of tests have been devised. The first test relates to the overall changes in land use which can be tabulated from LANDSAT data. Scenes for Franklin County for both 1973 and 1975 will be interpreted by Bendix Corporation and given to the State of Ohio on computer tapes. Based on these tapes, one can calculate the changes in land use in Franklin County during this period. The question which arises is how accurate are these land use change figures: Since LANDSAT has been in use for such a short time, no one appears to have utilized the data in this way or to test the accuracy of the results.

Fortunately, two sets of aerial photographs are available for Franklin County at times very close to those for LANDSAT imagery. Thus, the first step in compiling information for a test of LANDSAT involved the interpretation of land use change from these aerial photographs.

The initial task was to correlate the 1972 Franklin County aerial photographs (scale 1:1000) with the 1976 set (scale 1:2000). Upon completion and matching of the comparable mosaics with differing scales, the photographs were scanned on a zoom transfer scope for land use changes. Any differentials apparent in the two sets of photos were noted on the 1972 photos. We attempted to identify the entire area of change during this process, noting not merely the existence of a new structure but also its attendant property lines, if they were interested in land use changes only, differing crop patterns and water levels were considered extraneous.

Categorization of land use changes appeared under seven classifications: 1) Urban Recreation 2) Open Space - all land void of development that could not be identified as agricultural land 3) Agriculture 4) Com-

mercial - including trucking, airports, and warehousing operations 5) Industrial 6) Residential 7) Public - including schools, churches, and highways. A separate notation of "A" was utilized to signify land cleared and/or under construction and would be appended to the proper land use symbol.

Upon comparison of the areas on the 1972 set of aerial photos with the actual changes in the 1976 photos, each land use change was catalogued as outlined above, with the 1972 land use recorded as separated from the recorded 1976 land use change by a slash (e.g. 3/6). Certain decision rules were derived for classification of land uses as follows:

1) Commercial buildings - a higher parking lot to building ratio than industrial structures. Location along a major arterial. Location as related to residential development.

2) Industrial - location near interstate interchanges. Parking lot to building ratio lower than commercial. Landscaping and large front set back.

3) Additional buildings on a previously established land use was not noted, except in the case of new residential units in subdivision development.

4) Individual parcels in subdivisions cleared for development in 1972 and developed by 1976 were noted as 6A/6.

5) Agriculture - clear crop pattern with evidence of farm buildings in close proximity.

Once the classification was completed and noted on the 1972 photos, a planimeter was used to determine the aerial change. Thus, a table was derived detailing for each 1972 photo the land use changes on the photo with its before/after classifications, the area of land use change in square inches, and finally, this square inch measurement converted into acres. Table 55 shows these data.

In order to quantify the errors associated with LANDSAT at the pixel level, we made use again of the aerial photographs. First, the photos were oriented to the U.S.G.S. quadrangles using a zoom transfer scope. Then, a 1.1 acre grid of the same dimensions as LANDSAT pixels was overlayed on the mosaic of photos for each year, for a sample quadrangle in Franklin County. For each "pixel" the dominant land cover (greater than 50%) and the probable land use, if different, was recorded, encoded, and punched onto computer cards. In this way, a set of highly accurate land use information was produced which is compatible with the format of the LANDSAT data.

Table 55

LAND USE CHANGES IN FRANKLIN COUNTY BETWEEN 1972 AND 1976
(In Acres)

From \ To	Urban Recreation	Open Space	Agriculture	Commercial	Industrial	Residential	A* Residential	Public	Total
A* Urban Recreation	4.591								4.591
Open Space	136.823			1,154.270	637.052	4,210.055	328.053	686.869	7,153.122
Agriculture	344.582			366.850	709.826	2,278.466	219.927	61.983	3,981.634
A* Agriculture			16.758						16.758
Commercial								4.591	4.591
A* Commercial				196.281					196.281
Industrial		5.510							5.510
A* Industrial					220.156				220.156
Residential		8.724		68.871	14.233			20.202	112.030
A* Residential						2,542.470			2,542.470
A* Public								367.080	367.080
TOTAL	485.996	14.234	16.758	1,786.272	1,581.267	9,030.991	547.980	1,140.725	14,604.223

A* - under construction and/or land cleared for development
Source: 1972 (Flight No. 5010) and 1976 (Flight No. 5979) aerial photos of Franklin County with field checks.

FOOTNOTES

1. Ohio Farm Income, 1967, 1972. Ohio Agricultural Research and Development Center, Wooster, Ohio.

2. Ohio Crop Reporting Service, Ohio Agricultural Statistics, 1967, 1972, Ohio Crop Reporting Service, unpublished data.

3. Ohio Farm Bureau Federation, "Land Use Task Report", December 4, 1974.

4. U.S. Department of Agriculture, Statistical Reporting and Economic Research Service, 1973.

5. U.S. Department of Commerce, Bureau of the Census, Census of Agriculture, Ohio 1969.

6. Census of Agriculture, 1969.

7. Ohio Agricultural Research and Development Center, Ohio Farm Income 1967.

8. Ohio Agricultural Research and Development Center, Ohio Farm Income 1972.

9. Space Applications Board, Assembly of Engineering, Nat. Res. Council, Supporting Paper 3 Land Use Planning (Washington, D.C. Nat. Acad. Sci., 1974), pp. 31-32.

10. Bendix Aerospace Division, Computer Mapping of LANDSAT, Data for Environmental Applications (Ann Arbor, Michigan: Bendix Corporation, November 1975), p.8.

CHAPTER III-III

COMPUTER VERSION OF THE TAX MODELS-DOCUMENTATION

The statistical equations tested for the tax models were detailed above in the first two chapters. Given these results, those equations which were strongest (had the highest variance explained or R^2 values) were programmed to be used as a set of simulation models. This chapter summarizes and documents the basis and use of these computer models.

Basic Model Assumptions

The models which have been programmed for use in simulation are based on the regressions detailed in Chapters I and II. The basic assumptions of these models are as follows:

1) The models are an accurate representation of the relationship between tax base by category (dependent variables) and employment, population, agricultural production, and the presence of an SMSA (independent variables).

2) The historical trends with regard to tax base changes will continue into the future, i.e., no major revisions in the property tax system will be made.

3) An accurate, independent forecast of population, employment by category, and agricultural production is available for each county for each projection year.

Assumption 1 is simply a statement relating to the validation of the models. The validation procedure consisted of the statistical reliability of the models as measured by the R^2 values. Models with low reliability were dropped.

Assumption 2 is related to a basic premise of all modeling based on historical trends - that no dramatic changes in policy or shifts in taxing procedures will occur in the future. Such changes are one time occurrences which cannot be accounted for in this type of model.

The final assumption is a basic premise under which this research was initiated - that another, independent model would be used to forecast, for each county, population, employment by category, and agricultural production. As was demonstrated in our Phase II report, the DEMOS model does not supply reliable estimates of these parameters. Thus, the future use of the present models must be accompanied by other forecasts or models of these variables over time by county.

Uses of the Models

The models as programmed can be used to forecast property tax revenues (assessed value) by county in the following categories:

1) Agricultural land
2) Industrial land
3) Commercial land
4) Residential land
5) Agricultural land and buildings
6) Industrial land and buildings
7) Commercial land and buildings
8) Residential land and buildings

Given forecasts of employment by category, population, and agricultural production, one can forecast the probable tax revenues in each of these categories. In addition, one can forecast the number of industrial, commercial, and residential tax parcels. The models can thus be used as simulation tools relating to planning for land use and public service delivery. We have constructed several hypothetical examples of applications of the models in

order to illustrate better the potential uses to which they might be put.

Example 1

Let us hypothesize that planners in Geauga County, Ohio are attempting to formulate land use plans to the year 2000. In doing this, they have constructed a number of scenarios of county growth in terms of population and employment. One argument relating to their land use policy recommendations is that increases in population and employment will bring property tax revenues to the county and to local municipalities, which will be beneficial. Thus the argument goes, land use policies should be designed to allow for this type of population and employment increases. In order to quantify what these property tax impacts might be, the planners choose to utilize the tax models. For each projection of population and employment, they estimate, using the models, the property tax impacts in each of the relevant categories. In effect, they simulate the potential tax benefits. Then, using other estimates of the public service costs associated with the same development, they can construct a land use plan consistent with fiscal needs and community desires.

Example 2

For the second hypothetical example, let us suppose that a bill is introduced in the legislature which is designed to attract industry to Ohio. The bill would subsidize industries moving into the state in order to promote increased employment, and to offset the out-migration of people which has occurred in Ohio over the last decade. Proponents of the bill claim the subsidization will be more than offset by property taxes paid by the industries

and their employees. Opponents claim there is no basis to assume this. The governor's office asks to have some analysis done on this problem using hypothetical, example industries. Simulation of the property tax impacts of various estimates of increases in employment and population, is carried out using the tax models. Again, these can be compared with estimates of the costs to arrive at a subsidization rate which does not exceed the property tax and other revenues forthcoming from the new industries.

Instructions for Use of the Computerized Models

Figure 2 is a flow chart of the computerized versions of the tax models. The models can be accessed in two ways - using a program deck available at DECD, or, if the deck is placed on disk, through the State Data Center using the proper Job Control Language (JCL). The instructions given herein assume the program to be mounted on disk using a utility program. The only difference in using the program this way, and in employing the program deck, is in the JCL. The State Data Center can be consulted to obtain the proper cards for running the program using the deck.

I. A user of the model needs to prepare a card deck with three parts:

(1) JCL statements

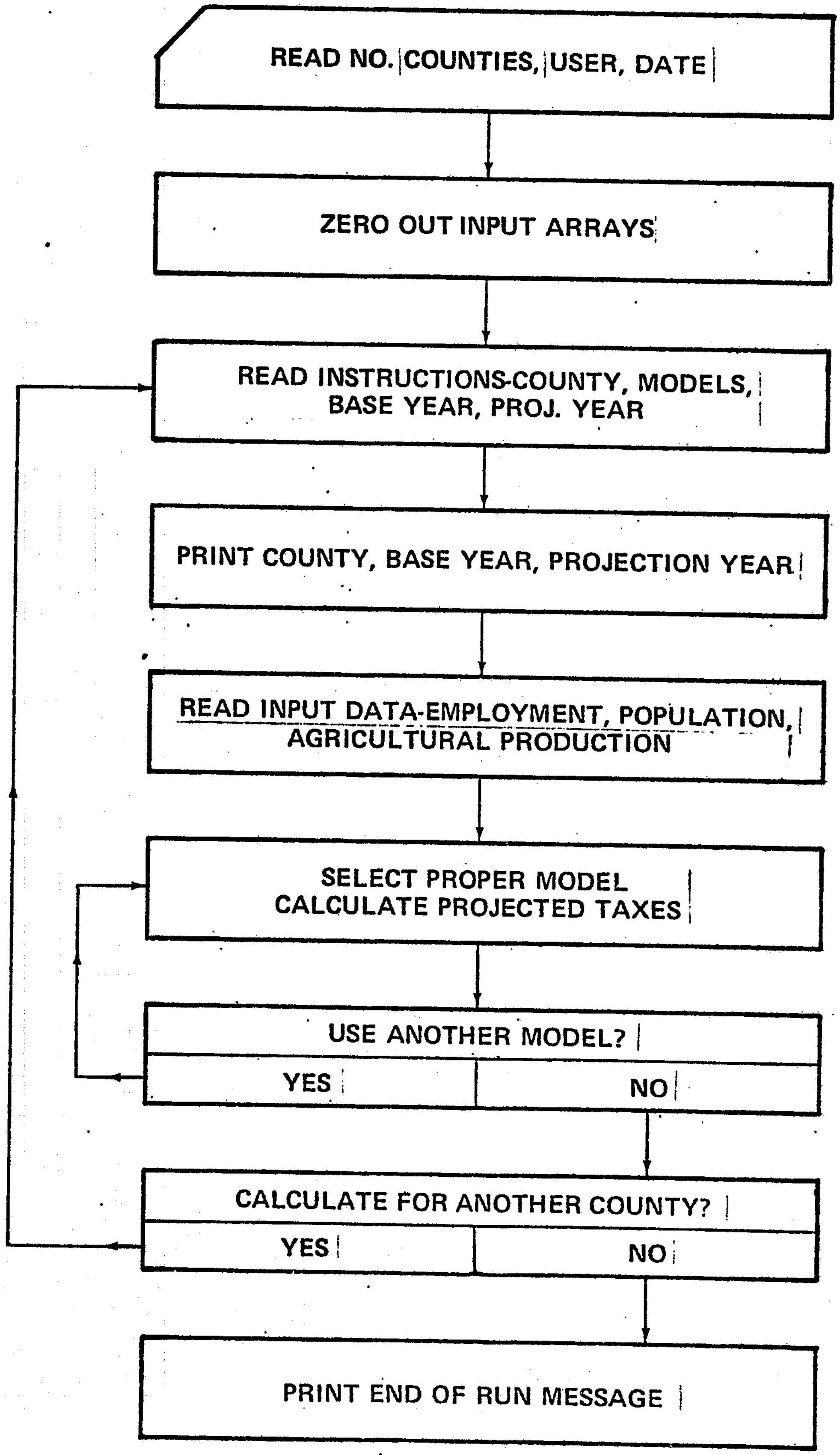
(2) Instruction card

(3) Input variable data cards

(1) JCL Statements

the user must have a State Data Center account and prepare a job card containing the necessary accounting information. This card is followed by one EXECUTE card and two DATA DEFINITION CARDS.

FIGURE 2.
FLOW CHART FOR
TAX MODEL COMPUTER PROGRAM



Col 1

```
//EXEC FORTHCLG

//FORT. SYSIN DD DSN=DECD,TAX,MODELS,DISP=OLD

//GO.SYSIN DD *
```

(2) Instruction Card

The instruction card identifies the user, the date, and the number of counties to be forecast. The data is entered as follows:

Col	1-2	Number of counties to be forecast (NOCNTY) (if one county is to be forecast more than once using alternative projections, each forecast counts once for this variable). Limit is five counties per run.
Col	3-5	User's name (USER)
Col	36-55	Date (DATE)

(3) Input Variable Data Cards.

For each county forecast indicated on the Instructions Card, a set of four input variable data cards must be prepared. Card 1 of this set is the instruction card for that forecast.

Col	1-20	Name of county (CNTY)
Col	21-23	Number of models to be run (NOMODS) See next card for list of 11 models
Col	24-27	Base year of projection period (BSYR)
Col	29-32	Target year of projection period (PRYR)

Card 2 of the set lists the models to be forecast for this county. Eleven models are available.

Model #	
1	Change in Assessed Value of Agricultural Land
2	Change in Assessed Value of Industrial Land
3	Change in Assessed Value of Commercial Land
4	Change in Assessed Value of Residential Land
5	Change in Assessed Value of Agricultural Land and Buildings
6	Change in Assessed Value of Industrial Land and Buildings
7	Change in Assessed Value of Commercial Land and Buildings
8	Change in Assessed Values of Residential Land and Buildings
9	Number of Industrial Parcels
10	Number of Commercial Parcels
11	Number of Residential Parcels

The card is prepared as follows:

	Col	1-3	Number of 1st Model Requested	IREQ(1)
(If any)	Col	4-6	" " 2nd " "	IREQ(2)
"	Col	7-9	" " 3rd " "	IREQ(3)
"	Col	10-12	" " 4th " "	IREQ(4)
"	Col	13-15	" " 5th " "	IREQ(5)
"	Col	16-18	" " 6th " "	IREQ(6)
"	Col	19-21	" " 7th " "	IREQ(7)
"	Col	22-24	" " 8th " "	IREQ(8)
"	Col	25-27	" " 9th " "	IREQ(9)
"	Col	28-30	" " 10th " "	IREQ(10)
"	Col	30-33	" " 11th " "	IREQ(11)

Card 3 of the set contains the projected values for the input variables in the following fields:

Col	1-10	Projected Population VARPR(1)
Col	11-20	Projected Total Employment VARPR(2)
Col	21-30	Projected Manufacturing Employment VARPR(3)
Col	31-40	Projected Service Employment VARPR(4)[1]
Col	41-50	Projected Crop Cash Receipts in 000's VARPR(5)
Col	51-60	Projected Livestock Cash Receipts in 000's VARPR(6)
Col	62	1 if county is part of an SMSA, 0 if not VARPR(7)

Card 4 of the set contains the assessed values for each land use in the county in the base year of the projection period in thousands of dollars in the following fields:

AVBS(1)	Col	1-11	Assessed Value of Agricultural Land
AVBS(2)	Col	11-20	Assessed Value of Industrial Land
AVBS(3)	Col	21-30	Assessed Value of Commercial Land
AVBS(4)	Col	31-40	Assessed Value of Residential Land
AVBS(5)	Col	41-50	Assessed Value of Agricultural Land and Buildings
AVBS(6)	Col	51-60	Assessed Value of Industrial Land and Buildings
AVBS(7)	Col	61-70	Assessed Value of Commercial Land and Buildings
AVBS(8)	Col	71-80	Assessed Value of Residential Land and Buildings

1 Service employment is the sum of employment in transportation and utilities, wholesale and retail, finance insurance, and services as defined by the Ohio Bureau of Employment Services.

The final set of input variable data cards should be followed by an end of file card. (/*) and an end of job card (//).
All numbers should be right justified; that is, the right most digit should be punched in the right most column of the indicated field.

A program listing, example data deck, and example output follow. The examples include a set of test runs with hypothetical counties, and a set of test runs with real, example counties. It must be voted that the results obtained in these runs are not dependable because the input projections use the DEMOS model and this has been found in error. However, the runs do illustrate the format of the model output.

The test run data are set up as follows:

Instructions card - 5 counties to be forecast by TEST RUNS (user's name)
On September 14, 1976.

Input Variable Data Cards

Card 1 - FIRST (county name)
Run 11 models
Base year 1967
Target year 1972

Card 2 - Lists models 1-11

Card 3 - Projected 1972 Population = 20500
Projected Total Employment = 2612
Projected Manu.Employment = 842
Projected Service Employment = 1160
Projected Crop Cash Receipts = $4222 thousand
Projected Livestock Cash Receipts = $6541 thousand
0 = county not in SMSA

Card 4 - Assessed value in 1967 (base year)
Agricultural land = 6384
Industrial land = 5
Commercial land = 265
Residential land = 1240
Agricultural land and buildings = 12013
etc.

Then begins the comparable data sets for counties
SECOND, THIRD, FOURTH, and FIFTH.

```
C
C           OHIO LAND ALLOCATION MODEL: TAX MODELS
C
C           DEVELOPED FOR DECD BY OSCAR FISCH AND
C           STEVE GORDON WITH A GRANT FROM NASA
C
C
C
C           PROGRAMMED BY HARVEY CURRAN
C
C
      DIMENSION VARPR(7),AVBS(8),IREQ(11),USER(8),DATE(5),CNTY(5)
C
C           READ USER DATA FOR RUN
C           WRITE HEADER PAGE
C
      READ(5,100) NOCNTY,USER,DATE
  100 FORMAT(I2,8A4,5A4)
      WRITE(6,50) USER,DATE
   50 FORMAT('1'/////5X,'OHIO LAND ALLOCATION MODEL: TAX BASE MODELS'///
     15X,8A4///5X,8A4)
      I=0
  111 I=I+1
      IF (I .EQ. (NOCNTY+1)) GO TO 199
C
C           ZERO OUT INPUT ARRAYS
C
      DO 212 J=1,7
  212 VARPR(J)=0.0
      DO 213 J=1,8
  213 AVBS(J)=0.0
      DO 214 J=1,11
  214 IREQ(J)=0
C
C           READ INSTRUCTIONS FOR COUNTY
C
      READ(5,200) CNTY,NOMODS,BSYR,PRYR
  200 FORMAT(5A4,I3,1X,A4,1X,A4)
      READ(5,300) IREQ
  300 FORMAT(11I3)
      IF (NOMODS .LT. 11) IREQ(NOMODS + 1) = 0
C
C           WRITE HEADER FOR COUNTY PAGE
C
      WRITE(6,1001) CNTY,BSYR,PRYR
 1001 FORMAT('1',30X,'TAX BASE PROJECTIONS FOR ',5A4,'COUNTY FROM ',
     1A4,' TO ',A4)
C
C           READ INPUT DATA FOR COUNTY
C
      READ(5,502) VARPR
      READ(5,503) AVBS
  502 FORMAT(6F10.0,F2.0)
  503 FORMAT(8F10.0)
C
C           WRITE BASE YEAR ASSESSED VALUES
C
       WRITE(6,1002)
 1002 FORMAT(///40X,'BASE YEAR ASSESSED VALUES '//41X,'LAND USE',20X,
```

```
                     1'LAND',11X,'LAND AND BUILDINGS')
0028                  DO 150 N=1,4
0029                  OUTA=AVBS(N)*1000.0
0030                  OUTB=OUTA+AVBS(N+4)*1000.0
0031                  IF (N .EQ. 1) WRITE(6,1003) OUTA,OUTB
0032                  IF (N .EQ. 2) WRITE(6,1004) OUTA,OUTB
0033                  IF (N .EQ. 3) WRITE(6,1005) OUTA,OUTB
0034                  IF (N .EQ. 4) WRITE(6,1006) OUTA,OUTB
0035             1003 FORMAT(41X,'AGRICULTURAL',11X,F12.0,10X,F12.0)
0036             1004 FORMAT(41X,'INDUSTRIAL   ',11X,F12.0,10X,F12.0)
0037             1005 FORMAT(41X,'COMMERCIAL   ',11X,F12.0,10X,F12.0)
0038             1006 FORMAT(41X,'RESIDENTIAL  ',11X,F12.0,10X,F12.0)
0039              150 CONTINUE
0040                  J=0
0041               20 J=J+1
0042                  IF (J .EQ. 12) GO TO 25
0043                  IF (IREQ(J) .EQ. 0) GO TO 25
0044                  MODEL=IREQ(J)
                C
                C
                C         CALCULATE AND WRITE MODEL VALUES
                C
0045                  GO TO (1,2,3,4,5,6,7,8,9,10,11),MODEL
0046                1 VALUE=((.701*VARPR(6)+1.179*VARPR(5)+5322.154*VARPR(7)+3340.624)-
                     1AVBS(1))*1000.0
0047                  VALUE=(VALUE+500.)/1000.
0048                  IVALUE=IFIX(VALUE)
0049                  VALUE=(FLOAT(IVALUE))*1000
0050                  WRITE(6,31) VALUE
0051               31 FORMAT(//10X,'PROJECTED CHANGE IN ASSESSED VALUE OF ',
                     1' AGRICULTURAL LAND',5X,'$',F12.0)
0052                  GO TO 99
0053                2 VALUE=(.028184*VARPR(3)**1.19937-AVBS(2))*1000.0
0054                   IF (VALUE .LE. 0.0) GO TO 98
0055                  VALUE=(VALUE+500.)/1000.
0056                  IVALUE=IFIX(VALUE)
0057                  VALUE=(FLOAT(IVALUE))*1000
0058                  WRITE(6,32) VALUE
0059               32 FORMAT(//10X,'PROJECTED CHANGE IN ASSESSED VALUE OF ',
                     1'INDUSTRIAL    LAND',5X,'$',F12.0)
0060                  GO TO 99
0061                3 VALUE=(.153004*VARPR(4)**1.16638-AVBS(3))*1000.0
0062                   IF (VALUE .LE. 0.0) GO TO 98
0063                  VALUE=(VALUE+500.)/1000.
0064                  IVALUE=IFIX(VALUE)
0065                  VALUE=(FLOAT(IVALUE))*1000
0066                  WRITE(6,33) VALUE
0067               33 FORMAT(//10X,'PROJECTED CHANGE IN ASSESSED VALUE OF ',
                     1'COMMERCIAL    LAND',5X,'$',F12.0)
0068                  GO TO 99
0069                4 VALUE=(.004794*VARPR(1)**1.35015-AVBS(4))*1000.0
0070                   IF (VALUE .LE. 0.0) GO TO 98
0071                  VALUE=(VALUE+500.)/1000.
0072                  IVALUE=IFIX(VALUE)
0073                  VALUE=(FLOAT(IVALUE))*1000
0074                  WRITE(6,34) VALUE
0075               34 FORMAT(//10X,'PROJECTED CHANGE IN ASSESSED VALUE OF ',
                     1'RESIDENTIAL   LAND',5X,'$',F12.0)
```


Program Listing (cont.)

```
      GO TO 99
    5 VALUE=((1.23398*VARPR(6)+1.28098*VARPR(5)+7016.744*VARPR(7)+
     17858.984)-AVBS(5))*1000.0
       IF (VALUE .LE. 0.0) GO TO 98
      VALUE=(VALUE+500.)/1000.
      IVALUE=IFIX(VALUE)
      VALUE=(FLOAT(IVALUE))*1000
      WRITE(6,35) VALUE
   35 FORMAT(//10X,'PROJECTED CHANGE IN ASSESSED VALUE OF ',
     1'AGRICULTURAL LAND AND BUILDINGS','$',F12.0)
      GO TO 99
    6 VALUE=(.927039*VARPR(3)**1.06487-(AVBS(2)+AVBS(6)))*1000.0
       IF (VALUE .LE. 0.0) GO TO 98
      VALUE=(VALUE+500.)/1000.
      IVALUE=IFIX(VALUE)
      VALUE=(FLOAT(IVALUE))*1000
      WRITE(6,36) VALUE
   36 FORMAT(//10X,'PROJECTED CHANGE IN ASSESSED VALUE OF ',
     1'INDUSTRIAL   LAND AND BUILDINGS','$',F12.0)
      GO TO 99
    7 VALUE=(1.313335*VARPR(4)**1.07888-(AVBS(3)+AVBS(7)))*1000.0
       IF (VALUE .LE. 0.0) GO TO 98
      VALUE=(VALUE+500.)/1000.
      IVALUE=IFIX(VALUE)
      VALUE=(FLOAT(IVALUE))*1000
      WRITE(6,37) VALUE
   37 FORMAT(//10X,'PROJECTED CHANGE IN ASSESSED VALUE OF ',
     1'COMMERCIAL   LAND AND BUILDINGS','$',F12.0)
      GO TO 99
    8 VALUE=(.065536*VARPR(1)**1.25601-(AVBS(4)+AVBS(8)))*1000.0
       IF (VALUE .LE. 0.0) GO TO 98
      VALUE=(VALUE+500.)/1000.
      IVALUE=IFIX(VALUE)
      VALUE=(FLOAT(IVALUE))*1000
      WRITE(6,38) VALUE
   38 FORMAT(//10X,'PROJECTED CHANGE IN ASSESSED VALUE OF ',
     1'RESIDENTIAL  LAND AND BUILDINGS','$',F12.0)
      GO TO 99
    9 VALUE=.01663*VARPR(3)
       IF (VALUE .LE. 0.0) GO TO 98
      WRITE(6,39) VALUE
   39 FORMAT(//10X,'PROVISIONAL PROJECTED NUMBER OF ',
     1'INDUSTRIAL  PARCELS',5X,F10.0)
      GO TO 99
   10 VALUE=.1135*DELSFR
       IF (VALUE .LE. 0.0) GO TO 98
      WRITE(6,40) VALUE
   40 FORMAT(//10X,'PROVISIONAL PROJECTED NUMBER OF ',
     1'COMMERCIAL  PARCELS',5X,F10.0)
      GO TO 99
   11 VALUE=.23963*VARPR(1)
       IF (VALUE .LE. 0.0) GO TO 98
      WRITE(6,41) VALUE
      GO TO 99
   41 FORMAT(//10X,'PROVISIONAL PROJECTED NUMBER OF ',
     1'RESIDENTIAL PARCELS',5X,F10.0)
   98 WRITE(6,960) MODEL,CNTY
  960 FORMAT(//10X,'NO SIGNIFICANT INCREASE IN MODEL    ',I2,
```

Program Listing (cont.)

220

```
                 1' FOR ',5A4,' COUNTY')
0126          99 GO TO 20
0127          25 GO TO 111
0128         199 CONTINUE
           C
           C        WRITE END OF RUN MESSAGE
           C
0129             WRITE(6,400) USER,DATE
0130         400 FORMAT('1','OHIO LAND ALLOCATION MODEL'///5X,'NORMAL COMPLETION'
                1///5X,8A4///5X,5A4)
0131             STOP
0132             END
```

Program Listing (cont.)

```
5  TEST RUNS                                SEPTEMBER 14, 1976
 FIRST                   11 1967 1972
1  2  3  4  5  6  7  8  9 10 11
  20500      2612        842      1160      4222       6541 0
   6384         5        265      1240     12013         88       1644       7140
SECOND                   11 1967 1972
1  2  3  4  5  6  7  8  9 10 11
 110100     38111      16124     19708      1034       8006 1
  26750      2495      12510     25731     38780      24531      37456     125717
THIRD                    11 1967 1972
1  2  3  4  5  6  7  8  9 10 11
  43800     12268       7097      4824      2584      13111 0
  10533       651       2113      9257     20821       6153       8696      45202
 FOURTH                  11 1967 1972
1  2  3  4  5  6  7  8  9 10 11
 100300     23934      12219     10783      5055      11211 1
  14552      2576       7660     20953     29914      21423      26910     106207
 FIFTH                   11 1967 1972
1  2  3  4  5  6  7  8  9 10 11
  57000      7550       1374      5686       413       3168 0
   4141        97       3328      6041      8300        966      13348      32118
```


Example Input Data Deck

OHIO LAND ALLOCATION MODEL

NORMAL COMPLETION

TEST RUNS

SEPTEMBER 14, 1976

Test Runs (cont.)

ORIGINAL PAGE IS OF POOR QUALITY

TAX BASE PROJECTIONS FOR FIRST COUNTY FROM 1967 TO 1972

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	6384000.	18396992.
INDUSTRIAL	5000.	93000.
COMMERCIAL	265000.	1909000.
RESIDENTIAL	1240000.	8380000.

PROJECTED CHANGE IN ASSESSED VALUE OF AGRICULTURAL LAND $ 6519593.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND $ 85894.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 309149.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 1938432.

PROJECTED CHANGE IN ASSESSED VALUE OF AGRICULTURAL LAND AND BUILDINGS$ 9325742.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 1115298.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 749024.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND AND BUILDINGS$ 8684218.

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 16.

PROVISIONAL PROJECTED NUMBER OF COMMERCIAL PARCELS 59779.

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 4912.

NO SIGNIFICANT INCREASE IN MODEL 11 FOR FIRST COUNTY

Test Runs (cont.)

TAX BASE PROJECTIONS FOR SECOND COUNTY FROM 1967 TO 1972

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	26750000.	6553000.
INDUSTRIAL	2495000.	2702984.
COMMERCIAL	12510000.	4996000.
RESIDENTIAL	25730992.	15144784.

NO SIGNIFICANT INCREASE IN MODEL 1 FOR SECOND COUNTY

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND $ 640602.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 3117433.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 5020640.

NO SIGNIFICANT INCREASE IN MODEL 5 FOR SECOND COUNTY

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 996633.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 6499203.

NO SIGNIFICANT INCREASE IN MODEL 8 FOR SECOND COUNTY

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 304.

PROVISIONAL PROJECTED NUMBER OF COMMERCIAL PARCELS 59779.

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 26383.

NO SIGNIFICANT INCREASE IN MODEL 11 FOR SECOND COUNTY

Test Runs (cont.)

3-111

TAX BASE PROJECTIONS FOR THIRD COUNTY FROM 1967 TO 1972

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	10533000.	31352984.
INDUSTRIAL	651000.	6804000.
COMMERCIAL	2113000.	10809000.
RESIDENTIAL	9257000.	54456992.

PROJECTED CHANGE IN ASSESSED VALUE OF AGRICULTURAL LAND. $ 5044964.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND. $ 520839.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 913601.

NO SIGNIFICANT INCREASE IN MODEL 4 FOR THIRD COUNTY

PROJECTED CHANGE IN ASSESSED VALUE OF AGRICULTURAL LAND AND BUILDINGS$ 6526746.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 4890765.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 1559910.

NO SIGNIFICANT INCREASE IN MODEL 8 FOR THIRD COUNTY

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 134.

PROVISIONAL PROJECTED NUMBER OF COMMERCIAL PARCELS 59779.

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 10496.

NO SIGNIFICANT INCREASE IN MODEL 11 FOR THIRD COUNTY

Test Runs (cont.)

TAX BASE PROJECTIONS FOR FOURTH COUNTY FROM 1967 TO 1972

BASE YEAR ASSESSED VALUES .

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	14552000.	44466000.
INDUSTRIAL	2576000.	25998992.
COMMERCIAL	7660000.	34570000.
RESIDENTIAL	20952992.	127159984.

PROJECTED CHANGE IN ASSESSED VALUE OF AGRICULTURAL LAND $ 7929527.

NO SIGNIFICANT INCREASE IN MODEL 2 FOR FOURTH COUNTY

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 74090.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 6161738.

PROJECTED CHANGE IN ASSESSED VALUE OF AGRICULTURAL LAND AND BUILDINGS $ 5271226.

NO SIGNIFICANT INCREASE IN MODEL 6 FOR FOURTH COUNTY

NO SIGNIFICANT INCREASE IN MODEL 7 FOR FOURTH COUNTY

NO SIGNIFICANT INCREASE IN MODEL 8 FOR FOURTH COUNTY

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 230.

PROVISIONAL PROJECTED NUMBER OF COMMERCIAL PARCELS 59779.

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 24035.

NO SIGNIFICANT INCREASE IN MODEL 11 FOR FOURTH COUNTY

Test Runs (cont.)

TAX BASE PROJECTIONS FOR FIFTH COUNTY FROM 1967 TO 1972

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	4141000.	12441000.
INDUSTRIAL	97000.	1063000.
COMMERCIAL	3328000.	16676000.
RESIDENTIAL	6641000.	28158992.

PROJECTED CHANGE IN ASSESSED VALUE OF AGRICULTURAL LAND $ 1907316.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND $ 66535.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 338352.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 6601792.

PROJECTED CHANGE IN ASSESSED VALUE OF AGRICULTURAL LAND AND BUILDINGS$ 3997277.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 972380.

NO SIGNIFICANT INCREASE IN MODEL 7 FOR FIFTH COUNTY

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND AND BUILDINGS$ 23487248.

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 26.

PROVISIONAL PROJECTED NUMBER OF COMMERCIAL PARCELS 59779.

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 13659.

NO SIGNIFICANT INCREASE IN MODEL 11 FOR FIFTH COUNTY

Test Runs (cont.)

OHIO LAND ALLOCATION MODEL: TAX BASE MODELS

TEST RUNS

FEBRUARY 15, 1977

Test Runs

Example runs use inaccurate projections.
Thus results are not reliable.

3-114

229

TAX BASE PROJECTIONS FOR STARK COUNTY FROM 1970 TO 1985

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	38786992.	61219984.
INDUSTRIAL	11170000.	76932992.
COMMERCIAL	50040000.	149820992.
RESIDENTIAL	119514992.	525351680.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND $ 7437000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 33124992.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 78640992.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 59254000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 115252992.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND AND BUILDINGS$ 272160000.

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 1340.

NO SIGNIFICANT INCREASE IN MODEL 10 FOR STARK COUNTY

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 104864.

Test Runs (cont.)

Example runs use inaccurate projections.

Thus results are not reliable.

ORIGINAL PAGE IS OF POOR QUALITY

TAX BASE PROJECTIONS FOR ATHENS COUNTY FROM 1970 TO 1985

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	4145000.	9415000.
INDUSTRIAL	119000.	2158000.
COMMERCIAL	3259000.	14739000.
RESIDENTIAL	6218000.	35244000.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND $ 277000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 7466000.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 7385000.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 2302000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 25124000.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND AND BUILDINGS$ 30748000.

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 54.

NO SIGNIFICANT INCREASE IN MODEL 10 FOR ATHENS COUNTY

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 14420.

Test Runs (cont.)

Example runs use inaccurate projections.

Thus results are not reliable..

TAX BASE PROJECTIONS FOR HAMILTO COUNTY FROM 1970 TO 1985

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	4365000.	5721000.
INDUSTRIAL	93724992.	401784832.
COMMERCIAL	187670992.	486898560.
RESIDENTIAL	427563776.	620973568.

NO SIGNIFICANT INCREASE IN MODEL 2 FOR HAMILTON COUNTY

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 82752992.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 217178000.

NO SIGNIFICANT INCREASE IN MODEL 6 FOR HAMILTON COUNTY

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 300058880.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND AND BUILDINGS$ 1768982780.

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 2595.

NO SIGNIFICANT INCREASE IN MODEL 10 FOR HAMILTON COUNTY

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 251260.

Test Runs (cont.)

Example runs use inaccurate projections.

Thus results are not reliable.

ORIGINAL PAGE IS OF POOR QUALITY

TAX BASE PROJECTIONS FOR DEFIANC COUNTY FROM 1970 TO 1985

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	19226992.	27282992.
INDUSTRIAL	806000.	10404000.
COMMERCIAL	2381000.	9987000.
RESIDENTIAL	6980000.	35036000.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND $ 337000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 2525000.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 2132000.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 1036000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 9349000.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND AND BUILDINGS$ 10422000.

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 131.

NO SIGNIFICANT INCREASE IN MODEL 10 FOR DEFIANCE COUNTY

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 10717.

Test Runs (cont.)

Example runs use inaccurate projections

Thus results are not reliable.

TAX BASE PROJECTIONS FOR NOBLE COUNTY FROM 1970 TO 1985

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	3476000.	6670000.
INDUSTRIAL	20000.	632000.
COMMERCIAL	212000.	1183000.
RESIDENTIAL	820000.	5973000.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND $ 82000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 605000.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 614000.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 702000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 2501000.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND AND BUILDINGS$ 2164000.

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 17.

NO SIGNIFICANT INCREASE IN MODEL 10 FOR NOBLE COUNTY

PROVISIONAL PROJECTED NUMBER OF PESIDENTIAL PARCELS 2724.

Test Runs (cont.)

Example runs use inaccurate projections.

Thus results are not reliable.

ORIGINAL PAGE IS OF POOR QUALITY

TAX BASE PROJECTIONS FOR LICKI... COUNTY FROM 1970 TO 1985

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	22484992.	41937984.
INDUSTRIAL	1278000.	16287000.
COMMERCIAL	6057000.	27413984.
RESIDENTIAL	24244992.	131073984.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND $ 1807000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 12279000.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 14608000.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 11336000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 38050000.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND AND BUILDINGS$ 44106992.

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 300.

NO SIGNIFICANT INCREASE IN MODEL 10 FOR LICKING COUNTY

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 31372.

Test Runs (cont.)

Example runs use inaccurate projections.

Thus results are not reliable.

235

TAX BASE PROJECTIONS FOR FRANKLIN COUNTY FROM 1970 TO 1985

BASE YEAR ASSESSED VALUES

LAND USE	LAND	LAND AND BUILDINGS
AGRICULTURAL	46772992.	56596992.
INDUSTRIAL	26768000.	136018000.
COMMERCIAL	205758992.	552355840.
RESIDENTIAL	323877888.	1206476800.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND $ 4443000.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND $ 90924000.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND $ 267490992.

PROJECTED CHANGE IN ASSESSED VALUE OF INDUSTRIAL LAND AND BUILDINGS$ 79546992.

PROJECTED CHANGE IN ASSESSED VALUE OF COMMERCIAL LAND AND BUILDINGS$ 307216896.

PROJECTED CHANGE IN ASSESSED VALUE OF RESIDENTIAL LAND AND BUILDINGS$ 998852864.

PROVISIONAL PROJECTED NUMBER OF INDUSTRIAL PARCELS 2063.

NO SIGNIFICANT INCREASE IN MODEL 10 FOR FRANKLIN COUNTY

PROVISIONAL PROJECTED NUMBER OF RESIDENTIAL PARCELS 235682.

Test Runs (cont.)

Example runs use inaccurate projections.

Thus results are not reliable.

CHAPTER III-IV

TESTS OF LANDSAT DATA AND MODELS

Chapter III of the Phase II report discusses the potential value of LANDSAT as a source of land use information and identifies some technical problems which many reduce its value. The purpose of this test is to determine whether or not the LANDSAT land use data can be used to formulate empirical models of land use change.

Chapter III identifies two types of potential error. The potential error associated with the misalignment of pixels from two different LANDSAT scenes is referred to as Error 1. The potential error associated with misclassification of land cover or land use due to similarities in spectral signatures is referred to as Error 2.

The report identifies three basic tests to be used in quantifying LANDSAT errors. The first test is a comparison of the overall land use changes indicated by LANDSAT to a reliable measure of land use change obtained from a photo interpretation. The second test is a pixel-by-pixel comparison of LANDSAT data to air photo data to quantify misclassification. The third test is a comparison of the 1975 LANDSAT scene to a scene flown one day later to test for misalignment. This assumes no changes should occur in one day. The test area was the southern half of the SW Columbus USGS quad. Two computer files had been prepared previously from air photos of the test area. These files were assumed to be an accurate picture of the land use and land cover in the test area in 1973 and 1975. (See Phase II, p. 41.)

Five files were prepared from Bendix LANDSAT data at DNR. Three of these files were direct translations of the LANDSAT files for the test area in 1973, 1975, and a one-day gap in 1975. Because the 1973 and 1975 LANDSAT files were found to be misaligned with respect to the quad boundaries, two adjusted files were prepared, one shifting the 1973 file two columns to the west and the other shifting the 1975 file two rows to the south.

The seven files used will be noted as follows:

73 Air	Air Photo 1973
75 Air	Air Photo 1975
73R	Unadjusted 1973 LANDSAT
75R	Unadjusted 1975 LANDSAT
73A	Adjusted 1973 LANDSAT
75A	Adjusted 1975 LANDSAT
75S	One day sidelap LANDSAT

All files except 73A are 15,750 pixels (90 rows x 175 pixels/row). 73A has only 173 pixels/row due to its shift. The shift was judged to have improved alignment to the quad boundaries because

(1) Water is the most stable category. 93 Pixels were water in both the 73R and 75R files, but 199 pixels matched as water in both the 73A and 75A files. Also, the LANDSAT and air photo files matched for 200 water pixels using 73A compared to only 160 using 73R and 405 pixels using 75A compared to 331 pixels using 75R.

(2) The 75A file matched the 75S file better than the 75R file matched the 75S file.

Pixels Agreeing	75R-75S	75A-75S
Urban	477	900
Res	1406	1718
Vacant	897	1204
Ag	3642	4240
3/	174	296
Water	228	422

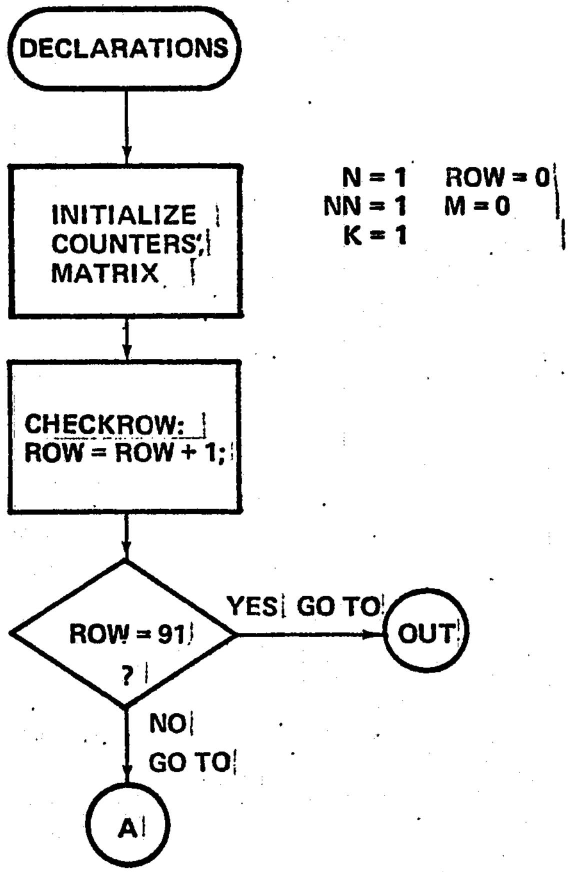
(3) In the Error 2 test, every category was better using the adjusted files, i.e., a larger percentage of pixels were properly classified. Thus, using the adjusted files will produce a more conservative and probably more accurate assessment of the errors associated with the LANDSAT data.

Two PL/1 programs were written to perform the tests. The first, called SWQUAD, was used to compare each LANDSAT file to the corresponding air photo file. Figure 3 is a flow chart of SWQUAD. The result of the program was a 15 x 35 matrix, in raw numbers and percentages, of the joint distribution of pixels among the 15 LANDSAT codes and 30 air photo codes. Each cell of the matrix M (I,J) indicates the number of pixels which were assigned LANDSAT Code I and air photo code J. For example M(4,12) would be the number of pixels which LANDSAT classified code 21, Agricultural Thick Vegetation, and the air photo interpretation classified code 31, Agricultural vegetation. The complete list of codes and indices is as follows in Table 56. The second program, CHANGES, was written to compare two LANDSAT files to two air photo files. Figure 4 is a flowchart of the CHANGES program. The categories were combined to reduce the number of possible outcomes to Industrial/Commercial, Residential, Vacant, and Agricultural. One air photo code, and three LANDSAT codes, were treated separately. The air photo code 7, Public has no corresponding LANDSAT code. There were about 1500 public pixels in each file.

LANDSAT codes 51 and 52, turbid and clear water were treated separately because there was no corresponding air photo code. LANDSAT code 80, unclassified was also separated for the same reason. LANDSAT code 33 in 1973 (Range Meadows) and 31 in 1975 (Range Reclaimed/Urban) was treated separately to test its content. No code 31's appear in 73R or 73A and no code 33's appear in 75R, 75A, or 75S.

The result of the program is a series of four matrices. The first, M1 is a 16 x 16 matrix, with the indices representing the following conditions (shown in Table 57).

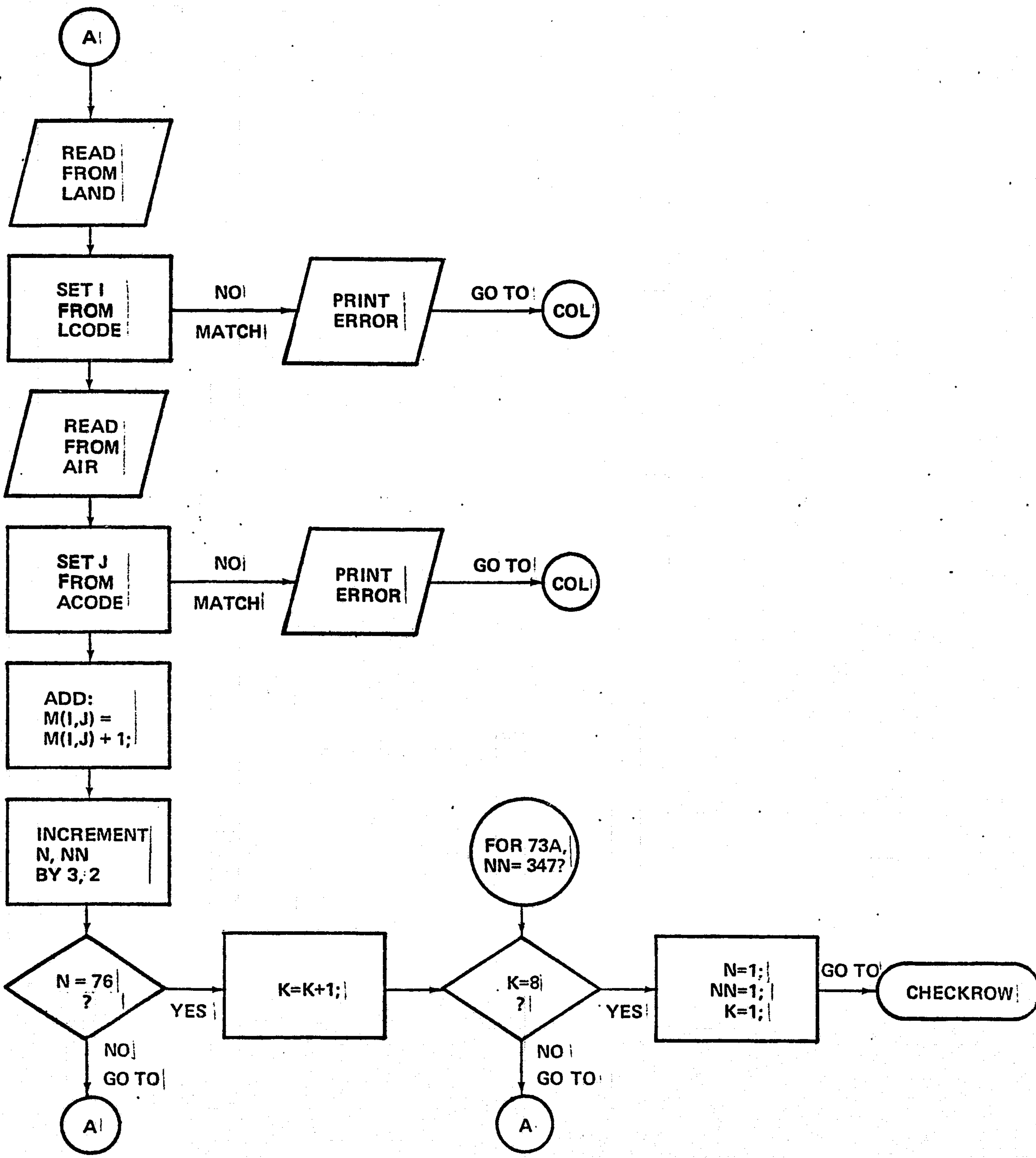
FIGURE 3.*
FLCW CHART:
PROC SWQUAD



* SEE KEY FOR EXPLANATION

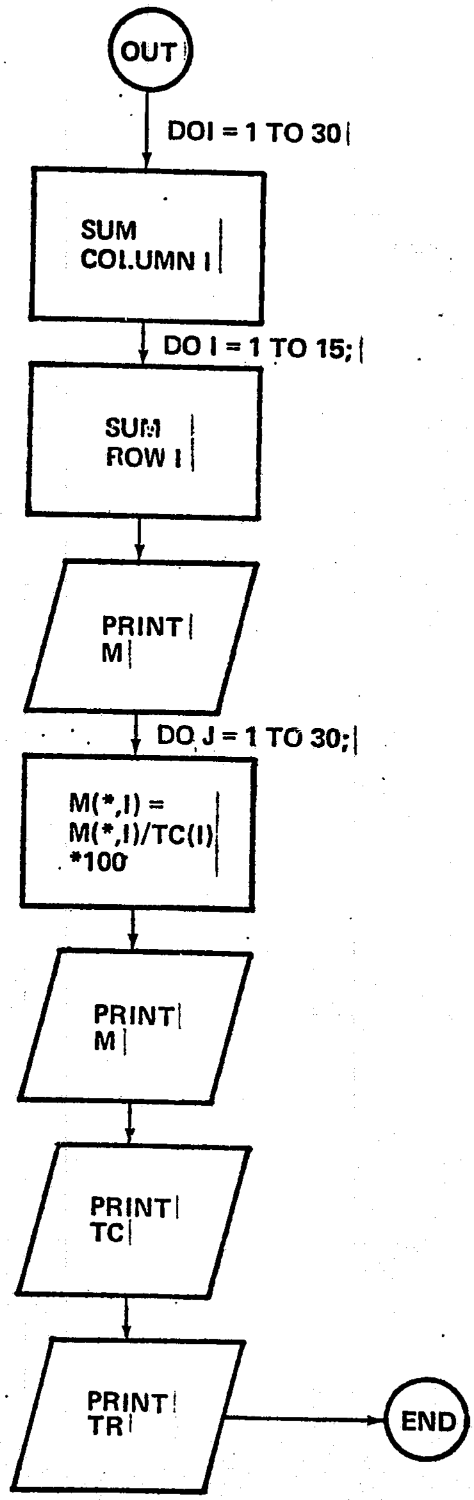
240

FIGURE 3


A
READ FROM LAND
SET I FROM LCODE
NO MATCH
PRINT ERROR
GO TO
COL
READ FROM AIR
SET J FROM ACODE
NO MATCH
PRINT ERROR
GO TO
COL
ADD: M(I,J) = M(I,J) + 1;
INCREMENT N, NN BY 3, 2
N = 76 ?
YES
K=K+1;
FOR 73A, NN= 347?
K=8 ?
YES
N=1; NN=1; K=1;
GO TO
CHECKROW
NO GO TO
A
NO GO TO
A

241

FIGURE 3.


OUT
DOI = 1 TO 30
SUM
COLUMN I
DO I = 1 TO 15;
SUM
ROW I
PRINT
M
DO J = 1 TO 30;
M(*,I) =
M(*,I)/TC(I)
*100
PRINT
M
PRINT
TC
PRINT
TR
END

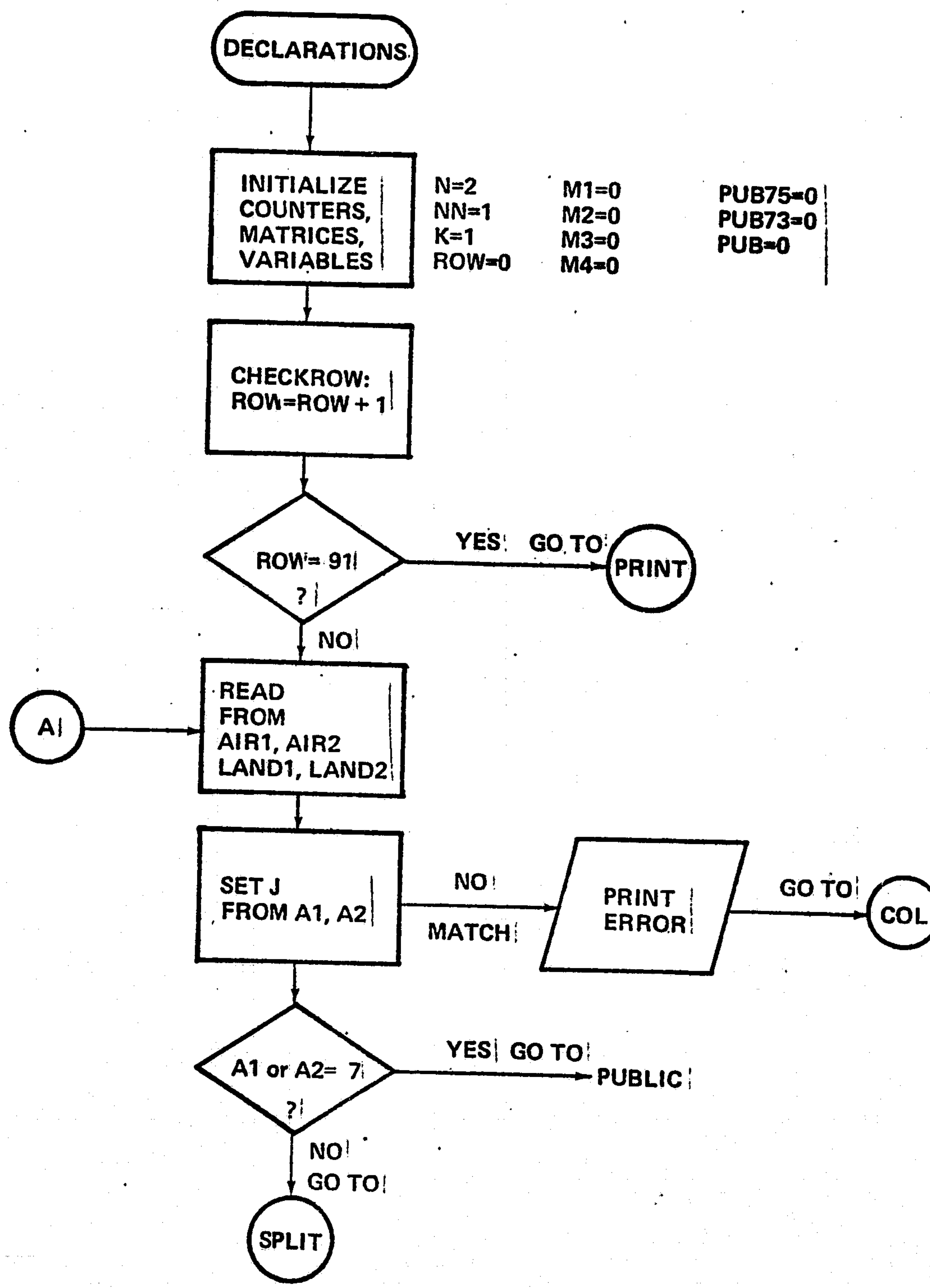
KEY TO FIGURE 3

DECLARE

FILES:	AIR	DISK FILE FROM AIR PHOTOS
	LAND	DISK FILE FROM LANDSAT
COUNTERS:	N	COLUMN COUNTER FOR AIR
	NN	COLUMN COUNTER FOR LAND
	K	ROW COUNTER FOR AIR
STRUCTURES:	M(15,30)	15 LANDSAT CODES X 30 AIR PHOTO CODES
	TR(15)	ROW TOTALS FOR M
	TC(30)	COLUMN TOTALS FOR M
VARIABLES:	ACODE, LCODE	CODE FOR PIXEL FROM AIR, LAND

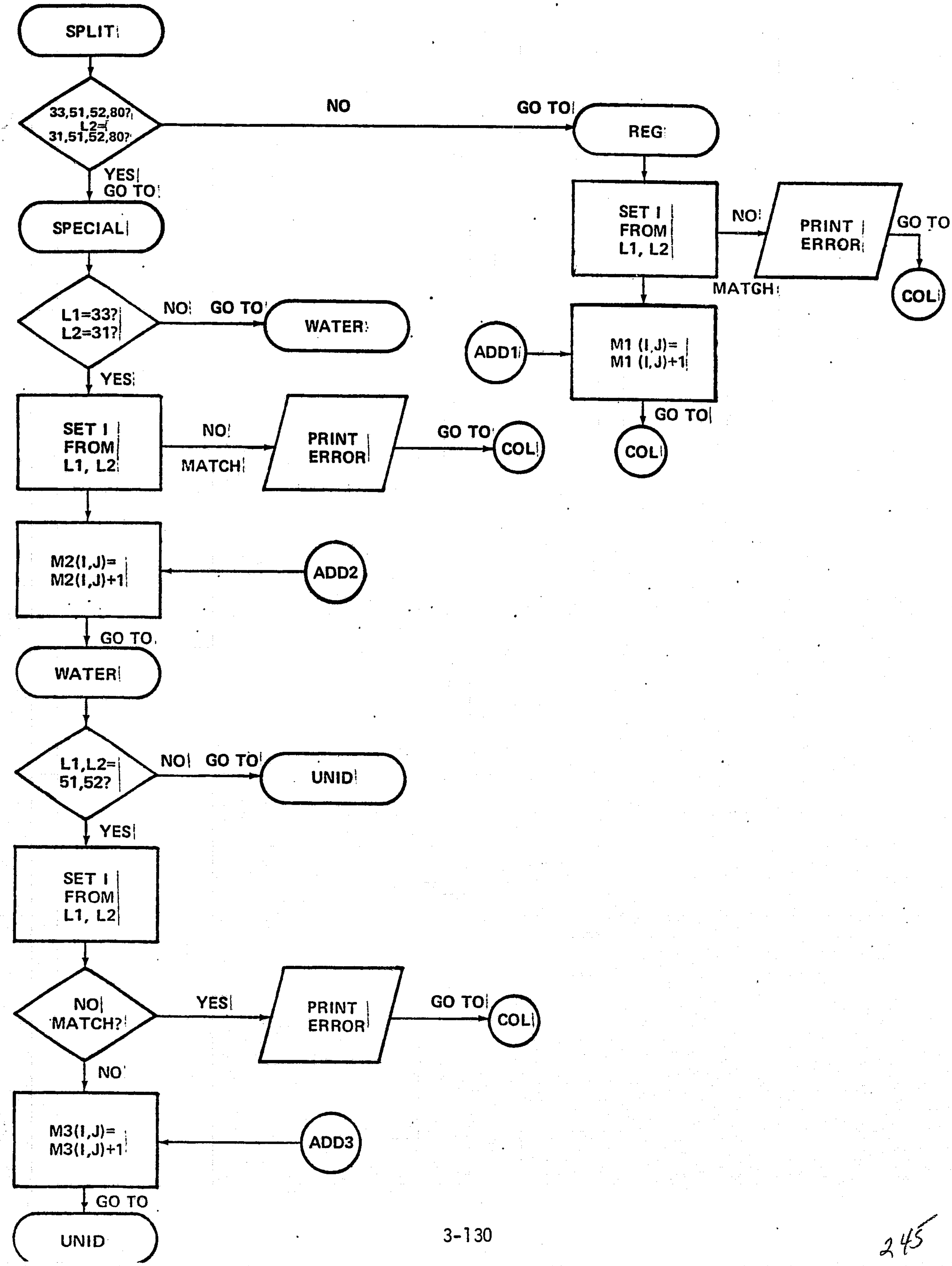
FIGURE 4.*

FLOW CHART:
PROCEDURE CHANGES



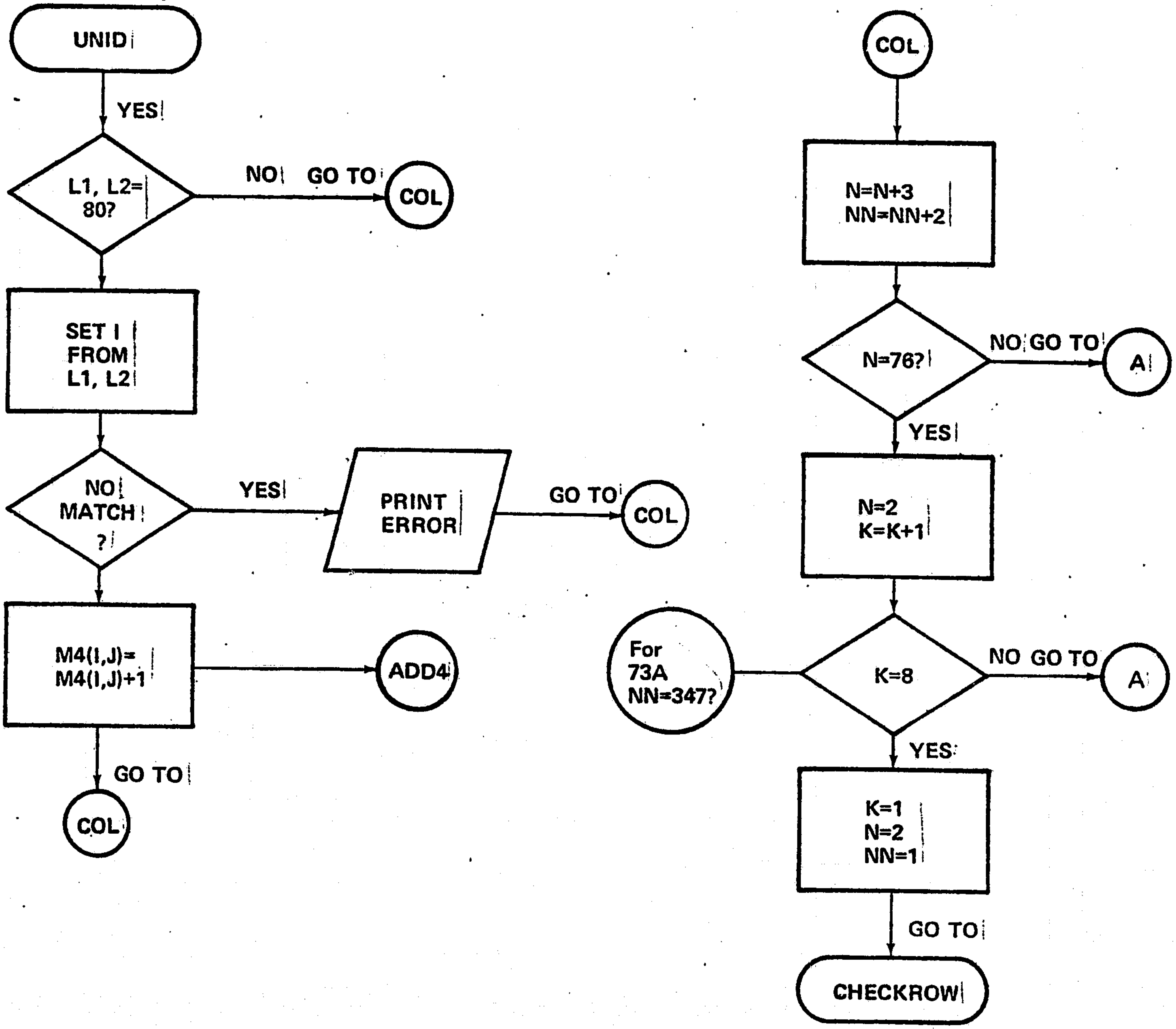
*SEE KEY FOR EXPLANATION

FIGURE 4


SPLIT
33,51,52,80?
L2=
31,51,52,80?
NO
GO TO
REG
YES
GO TO
SPECIAL
SET I
FROM
L1, L2
NO
MATCH
PRINT
ERROR
GO TO
COL
L1=33?
L2=31?
NO
GO TO
WATER
ADD1
M1 (I,J)=
M1 (I,J)+1
GO TO
COL
YES
SET I
FROM
L1, L2
NO
MATCH
PRINT
ERROR
GO TO
COL
M2(I,J)=
M2(I,J)+1
ADD2
GO TO
WATER
L1,L2=
51,52?
NO
GO TO
UNID
YES
SET I
FROM
L1, L2
NO
MATCH?
YES
PRINT
ERROR
GO TO
COL
NO
M3(I,J)=
M3(I,J)+1
ADD3
GO TO
UNID

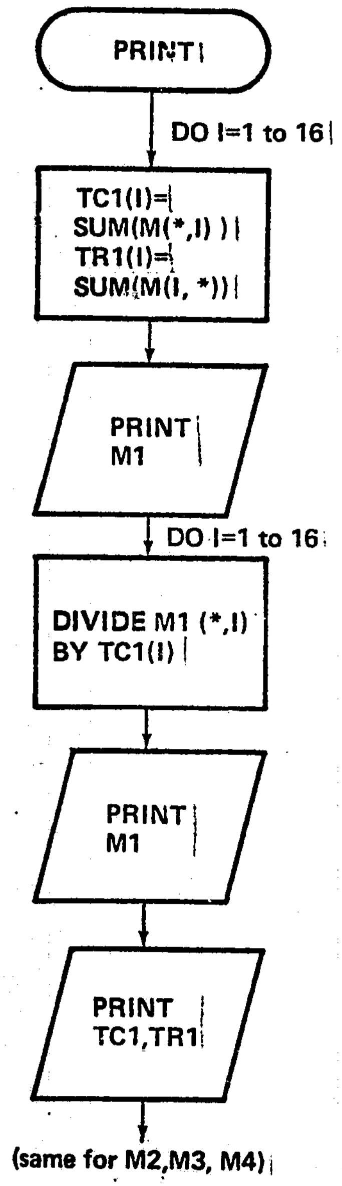
245

FIGURE 4


UNID
YES
L1, L2=
80?
NO
GO TO
COL
SET I
FROM
L1, L2
NO
MATCH
?
YES
PRINT
ERROR
GO TO
COL
M4(I,J)=
M4(I,J)+1
ADD4
GO TO
COL
COL
N=N+3
NN=NN+2
N=76?
NO GO TO
A
YES
N=2
K=K+1
For
73A
NN=347?
K=8
NO GO TO
A
YES
K=1
N=2
NN=1
GO TO
CHECKROW

246

FIGURE 4


PRINT
DO I=1 to 16
TC1(I)=
SUM(M(*,I))
TR1(I)=
SUM(M(I, *))
PRINT
M1
DO I=1 to 16
DIVIDE M1 (*,I)
BY TC1(I)
PRINT
M1
PRINT
TC1,TR1
(same for M2,M3, M4)

KEY TO FIGURE 4

DECLARE:

FILES:	AIR 1	1973 AIR PHOTO OR 1975 AIR PHOTO
	AIR 2	1975 AIR PHOTO OR NONE FOR 75A-75S COMPARISC
	LAND 1	1973 A OR 1975A LANDSAT
	LAND 2	1975A or 1975S LANDSAT
COUNTERS:	N	AIR1, AIR2 COLUMN COUNTER
	NN	LAND1, LAND2 COLUMN COUNTER
	K	AIR1, AIR2 ROW COUNTER
STRUCTURES:	M1(16,16)	REGULAR CHANGE MATRIX
	TC1(16)	M1 COLUMN TOTALS
	TR1(16)	M2 ROW TOTALS
	M2(13,16)	31/33 CHANGE MATRIX
	TC2(16)	M2 COLUMN TOTALS
	TR2(13)	M2 ROW TOTALS
	M3(13,16)	WATER CHANGE MATRIX
	TC3(16)	M3 COLUMN TOTALS
	TR3(13)	M3 ROW TOTALS
	M4(13,16)	UNCLASSIFIED CHANGE MATRIX
	TC4(16)	M4 COLUMN TOTALS
	TR4(13)	M4 ROW TOTALS
VARIABLES:	A1, A2	PIXEL CODE FROM AIR1, AIR2
	L1, L2	PIXEL CODES FROM LAND1, LAND2
	PUB73	PUBLIC PIXELS 1973
	PUB75	PUBLIC PIXELS 1975
	PUB	PUBLIC PIXELS BOTH YEARS

TABLE 56

Matrix Indices for SWQUAD

LANDSAT CODES	I*
1-Urban	
11-Center	1
12-Residential	2
13-Residential/Range	3
2-Agricultural	
21-Thick Vegetation	4
22-Thin Vegetation	5
23-Bare Earth	6
24-Pasture	7
3-Range	
31-Reclaimed/Urban	8(75A, 75S)
33-Meadows	8(73A)
34-Grassland	9
4-Forest	
41-Forest	10
5-Water	
51-Turbid	11
52-Clear	12
7*Barren	
73-Quarry	13
74-Sand	14
80-Unclassified	15

AIR PHOTO CODES	J*
1-Recreation	
10-Bare Earth	1
11-Vegetation	2
12-Water	3
14-Buildings	4
15-Concrete/Asphalt	5
2-Open Space	
20-Bare Earth	6
21-Vegetation	7
22-Water	8
24-Buildings	9
25-Concrete/Asphalt	10
3-Agriculture	
30-Bare Earth	11
31-Vegetation	12
32-Water	13
34-Buildings	14
35-Concrete-Asphalt	15
4-Commercial	
40-Bare Earth	16
41-Vegetation	17
42-Water	18
44-Buildings	19
45-Concrete/Asphalt	20
5-Industrial	
50-Bare Earth	21
51-Vegetation	22
52-Water	23
54-Buildings	24
55-Conrete/Asphalt	25
6-Residential	
60-Bare Earth	26
61-Vegetation	27
62-Water	28
64-Buildings	29
65-Concrete/Asphalt	30
7-Public	
70-Bare Earth	31
71-Vegetation	32
72-Water	33
74-Buildings	34
75-Concrete/Asphalt	35

* Codes used in computer program

TABLE 57

Matrix Indices for CHANGES M1(16,16)

(LANDSAT) [Air Photo]	(Rows) I	(Columns) J
From:		
Industrial/Commercial (11) [4,5]		
To:		
I/C (11) [4,5]	1	1
Residential (12,13) [6]	2	2
Vacant (34,41,73,74) [1,2]	3	3
Agriculture (21,22,23,24) [3]	4	4
From:		
Residential (12,13) [6]		
To:		
Residential (12,13)	5	5
I/C (11)	6	6
Vacant	7	7
AG	8	8
From:		
Vacant (34,41,73,74) [1,2]		
To:		
Vacant	9	9
I/C	10	10
Res	11	11
AG	12	12
From:		
Agriculture (21,22,23,24) [3]		
To:		
AG	13	13
I/C	14	14
Res	15	15
Vacant	16	16

The diagonal elements represent the pixels for which both LANDSAT and the air photos agree as to the land use change.

The second matrices, M2, M3 and M4 are 13 x 16 matrices, the columns being the same as M1, but the rows representing those in Table 58.

The final output is the number of public pixels in 1973, the number of public pixels in 1975, and the number of pixels recorded as public in both years.

Table 58

[Equivalence between M2, M3, and M4 change matrices and three LANDSAT categories treated separately.]

(Rows) I	Categories and Equivalence 31/33	Water	Unidentified
1	31-31	5x-5x	80-80
2	31-I/C	5x-I/C	80-I/C
3	31-Res	5x-Res	80-Res
4	31-Vac	5x-Vac	80-Vac
5	31-Ag	5x-Ag	80-Ag
6	31-5x	5x-31	80-31
7	31-80	5x-80	80-5x
8	I/C-31	I/C-5x	I/C-80
9	Res-31	Res-5x	Res-80
10	Vac-31	Vac-5x	Vac-80
11	Ag-31	Ag-5x	Ag-80
12	5x-31	31-5x	31-80
13	80-31	80-5x	5x-80

Table 59 LANDSAT DISTRIBUTION AMONG THREE SCENES

PIXELS (PERCENTAGE)

Category	73	73A	75	75A	75S
11	349 (2.2)	349 (2.2)	454 (2.8)	457 (2.9)	576 (3.7)
12	0 (0.0)	0 (0.0)	2164 (13.7)	2281 (14.5)	2640 16.8
13	4839 30.7	4809 30.8	1165 7.4	1214 7.7	671 4.3
21	6210 39.4	6113 39.3	509 3.2	474 3.0	273 1.7
22	1479 9.4	1450 9.3	7283 46.2	7186 45.6	5494 34.9
23	57 .4	56 .4	47 .3	46 .3	22 .1
24	0	0	421 2.7	433 2.7	234 1.5
31/33	1445 9.2	1439 9.2	1114 7.1	1098 7.0	2486 15.8
34	250 1.6	250 1.6	430 2.7	392 2.5	178 1.1
41	156 1.0	155 1.0	807 5.1	821 5.2	1693 10.7
51	312 2.0	312 2.0	632 4.0	632 4.0	663 4.2
52	0	0	30 .2	30 .2	59 .4
73	212 1.3	202 1.3	348 2.2	346 2.2	390 2.5
74	152 1.0	148 1.0	278 1.8	272 1.8	285 1.8
80	289 1.8	287 1.8	68 .4	68 .4	86 .5
TOTAL	15750	15570	15750	15750	15750

Test Results

Before considering Error 1 and Error 2 it is necessary to discuss the inconsistency of the training sets for the three LANDSAT scenes (73,75,75S). First, codes 12,24,31, and 52 do not appear in the 1973 scene and code 33 appears only in the 1973 scene. Second, the number of pixels in several categories vary illogically among the three scenes. Table 59 shows the distribution of pixels among the LANDSAT categories.

Overall Land Use Change

Some peculiar results are also obtained in the categorization of overall land use change: These are shown in Table 60.

TABLE 60

	ACRES		
	73A-75A	73A-75S	Air Photo
Ind/Comm	+118.8	+249.7	+125.4
Res	-1445.5	-1647.8	+366.3
Vacant	+1161.6	+1970.1	-480.7
Ag	+572.0	-1855.6	-26.4
Public	---	---	_15.4

Note: Pixels with LANDSAT codes 31,33,51,52,80 in either scene excluded.

Error 1

Comparison of the 75A and 75S LANDSAT files was used to test the extent of Error 1 (misalignment). The test assumes that no change should be found in one day unless misalignment errors occur. Using the four aggregated categories (Industrial/Commercial, Residential, Vacant and Agriculture), the results show that roughly 60% of the Ind/Comm, Res, and Ag category pixels matched, and 35.8% of the Vacant category pixels matched. The previously noted differences in the training sets make these results difficult to interpret. Much of the 40% - 65% misalignment may have resulted from the training set problem.

Error 2

Comparisons of each LANDSAT file to the corresponding air photo files revealed many misclassification problems. As anticipated, the main problem is land uses that have similar land covers. Tables 61-65 show the percent correct classifications and the primary misclassifications for each air photo land use category except Recreation and Public. Recreation was not analyzed because it contained fewer than 200 pixels. Public was not analyzed because it contained pixels like each of the other categories except for public ownership and analysis would be redundant. One air photo industrial code, 52 (Industrial Water) was excluded from the industrial analysis because not all LANDSAT water pixels were quarries.

LANDSAT performed best for Open Space (88% correct for 75S) and worst for industrial (15%) and commercial (10%). Changes in the training sets improved commercial and open space accuracy, but the change for 75S reduced accuracy for agriculture. The doubling of the number of forest pixels during the one day gap supports recent evidence of corn fields being labelled forest in the latest training sets.

The conclusion of the Error 2 test is that substantial errors do exist. Modification of the results is made difficult by the spread across time categories of some codes (See Table 56). An algorithm for adjustment would be difficult to construct.

Analysis of LANDSAT Errors

Open Space

	73	Adj. 73	75	Adj. 75	Side 75
No. of Pixels	4900	4853	4463	4463	4463
% Correct	70.5	72.5	80.1	88.2	85.2
Correct Categories:					
AG Thick Veg.	2521 51.4	2583 53.2	203 4.5	230 5.2	108 2.4
AG Thin Veg.	381 7.8	378 7.8	2555 57.2	2776 62.2	2105 47.2
Meadows	359 7.3	337 6.9	259 5.8	268 6.0	673 15.1
Grasslands	132 2.7	146 3.0	153 3.4	150 3.4	66 1.5
Forest	66 1.3	77 1.6	294 6.6	410 9.2	779 17.5
Pasture	0	0	114 2.6	100 2.2	67 1.5
Errors Categories:					
13	1191 24.3	1129 23.3	256 5.7	148 3.3	94 2.1
73	50 1.0	47 1.0	100 2.2	37 .8	81 1.8
74	25 .5	24 .5	35 .8	8 .2	14 .3
80	98 2.0	87 1.8	10 .2	12 .3	12 .3
11	34 .7	16 .3	49 1.1	26 .6	50 1.1
12	0	0	398 8.9	261 5.8	369 8.3

256

Analysis of LANDSAT
Data Agriculture

	73	A 73	75	A 75	S 75
No. of Pixels	2459	2459	2436	2436	2436
% Correct	60.4	61.3	76.4	76.5	59.6
Correct Categories:					
21	1221 49.7	1267 51.5	200 8.2	219 9.0	134 5.5
22	242 9.8	227 9.2	1591 65.3	1582 64.9	1289 52.9
23	23 .9	15 .6	5 .2	12 .5	3 .1
24	0	0	65 2.7	50 2.1	27 1.1
Error Categories:					
13	648 26.4	634 25.8	19 .8	10 .4	26 1.1
33/31	187 7.6	184 7.5	129 5.3	125 5.1	302 12.4
34	31 1.3	37 1.5	150 6.2	181 7.4	77 3.2
41	44 1.8	47 1.9	204 8.4	221 9.1	519 21.3
73	27 1.1	19 .8	6 .2	1 .04	4 .2
74	25 1.0	19 .8	1 .04	0	0
80	11 .4	10 .4	8 .3	9 .4	4 .2
12	0	0	52 2.1	24 1.0	49 2.0

Table 63

Analysis of LANDSAT
Data Commercial

	73	Adjusted 73	75	Adjusted 75	Sidelap 75
No. of Pixels	673	657	720	720	720
% Correct:	.6	.9	7.5	8.5	7.1
(11) Urban Center	4	6	54	61	51
Major Errors:					
(13) Res Range	277	284	59	95	51
	41.2	43.2	8.2	13.2	7.1
(21) Ag Thick Veg	238	204	18	5	2
	35.4	31.2	2.5	.7	.3
(22) Ag Thin Veg	51	58	291	195	189
	7.6	8.8	40.4	27.1	26.3
(33) Meadows (31) R/U (75)	52	52	41	58	126
	7.6	7.9	5.7	8.1	17.5
(73) Quarry	23	26	18	34	23
	3.4	4.0	2.5	4.7	3.2
(12) Res	0	0	153	164	144
			21.3	22.8	20.0
(41) Forest	2	3	16	9	34
	.3	.5	2.2	1.3	4.7
	647	613	640	619	590
Pasture				48	41
				6.7	5.7

Definitely changed training sets for:

- Res Range
- Urban Res
- Range/Urban/Reclaimed
- Ag Thick Veg
- Ag Thin Veg

Analysis of LANDSAT
Data Industrial (No Water)

	73	Adj. 73	75	Adj. 75	Sidelap 75
No. of Pixels	1420	1379	1487	1487	1487
Correct %	10.4	12.9	10.0	11.4	10.8
(11) Urban Center	147	178	149	170	161
Major Error Categories:					
12	0	0	242 16.3	236 15.8	244 16.4
13	349 24.6	331 24.0	130 8.7	152 10.2	160 10.8
21	406 28.5	448 32.5	6 .4	4 .3	2 .1
22	229 16.1	225 16.3	287 19.3	279 18.8	286 19.2
31/33	68 4.8	73 5.3	133 8.9	135 9.1	183 12.3
41	8 .6	5 .4	56 3.8	34 2.3	58 3.9
51	122 8.6	93 6.7	228 15.3	152 10.2	161 10.8
73	49 3.5	64 4.6	69 4.6	84 5.6	73 4.9
74	52 3.7	64 4.6	150 10.1	169 11.4	172 11.6
80	46 3.2	47 3.4	21 1.4	22 1.5	29 2.0

Analysis of LANDSAT Data Residential

	73	Adj. 73	75	Adj. 75	Sidelap 75
No. of Pixels	3808	3850	4201	4201	4201
Correct %	43.1	49.5	33.7	41.3	42.3
12	0	0	856 20.4	1082 25.8	1361 32.4
13	1666 43.1	1773 49.5	558 13.3	651 15.5	341 8.1
Major Error Categories:					
21	1318 34.1	1208 33.7	61 1.5	4 .1	5 .1
22	164 4.2	156 4.4	1934 46.0	1846 43.9	1263 6.3
31/33	583 15.0	596 16.6	264 6.3	232 5.5	723 17.2
80	48 1.2	46 1.3	9 .2	5 .1	10 2.4
11	11 .3	7 .2	38 .9	30 .7	60 1.4
24	0	0	146 3.5	123 2.9	46 1.1
34	18 .5	19 .5	76 1.8	35 .8	16 .4
41	20 .5	14 .4	132 3.1	55 1.3	177 4.2
73	21 .5	17 .5	63 1.5	76 1.8	117 2.8

Analysis of LANDSAT Data-Problem Categories

			73A		75A		75S	
LANDSAT:	12		0		2281		2640	
Air:	1	Rec	0		43	1.9	35	.2
	2	Open	0		275	12.1	369	14.0
	3	Ag	0		24	1.1	49	1.9
	4	Comm	0		164	7.3	154	5.8
	5	Ind	0		347	15.2	331	12.5
Match	6	Res	0		1082	47.4	1361	51.6
	7	Pub	0		350	15.3	341	12.9
LANDSAT:	13		4809		1.214		671	
Air:	1	Rec	75	1.6	10	.8	7	1.0
	2	Open	1129	23.4	148	12.2	94	14.0
	3	Ag	634	13.1	10	.8	26	3.9
	4	Comm	284	5.9	95	7.8	51	7.6
	5	Ind	474	9.9	175	14.4	103	15.4
Match	6	Res	1773	36.9	651	53.6	341	50.8
	7	Pub	440	9.1	125	10.3	49	7.3
LANDSAT:	21		611.3		474		273	
Air:	1		71	1.2	0		0	
	2		2583	42.3	230	48.5	108	39.6
Match	3	Ag	1267	20.7	219	46.2	134	49.1
	4		204	3.3	5	1.1	2	.7
	5		345	5.6	5	1.1	2	.7
	6		1208	19.8	4	.8	5	1.8
	7		435	7.1	11	2.3	22	8.1
LANDSAT:	51		312		632		663	
Air:								
Ind Water	42	MATCH	176	56.4	37.3	59.0	339	51.1
	21		0		9	1.4	33	5.0
Pub. Water	72		24	7.7	32	5.1	52	7.8
Ind Bare	50		56	17.9	106	16.8	102	15.4
Ind Veg	51		22	7.1	28	4.4	42	6.3
	Other		34	10.9	84	13.3	95	14.3
LANDSAT:	80		287		68		86	
Air:	1		0		2	2.9	0	
	2		87	30.3	12	17.6	12	14.0
	3		10	3.5	9	13.2	4	4.7
	4		9	3.1	4	5.9	5	5.8
	5		81	28.2	33	48.5	41	47.7
	6		46	16.	5	7.4	10	11.6
	7		54	18.8	3	4.4	14	16.3

Problem Codes

			73A		75A		75S	
LANDSAT:	22		1450		7186		5494	
AIR:	1		14	1.0	60	8.3	49	.9
	2		378	26.1	2776	38.6	2105	38.3
	3	Ag	228	15.7	1584	22.0	1289	23.5
	4		58	4.0	195	2.7	189	3.4
	5		361	24.9	317	4.4	265	4.8
	6		156	10.8	1846	25.7	1273	23.2
	7		255	17.6	408	5.7	324	5.9
LANDSAT:	31/33		1439		1098		2486	
AIR:	1		23	1.6	20	1.8	46	1.9
MATCH	2	Open	337	23.4	268	24.4	673	27.1
	3		184	12.8	125	11.4	302	12.1
	4		52	3.6	58	5.3	126	5.1
	5		83	5.8	294	26.8	283	11.4
	6		596	41.4	232	21.1	723	29.1
	7		164	11.4	201	18.3	333	13.4
LANDSAT:	41		155		821		1693	
	1		0		4	.5	0	
MATCH	2	Open	77	49.7	410	49.9	779	46.0
	3		47	30.3	221	26.9	521	30.7
	4		3	1.9	9	1.1	44	2.6
	5		9	5.8	53	6.5	67	4.0
	6		14	9.0	55	6.7	177	10.5
	7		5	3.2	69	8.4	105	6.2

Tests of LANDSAT Data in Socio-Economic Models

The micro-level tests of the LANDSAT data would indicate a high degree of doubt with regard to the accuracy of the data. It may be, however, that at a macro level of analysis - the county - the summary data for LANDSAT are more accurate and that they may yet fit a statistical model such as the tax models. In order to test this hypothesis summary data were obtained for the 1976 LANDSAT interpretation of Ohio for 76 of the 88 counties in Ohio. The data for the remaining twelve counties were not available but an 86% sample is more than sufficient to test the statistical reliability of the data.

Data were obtained on tape from the Ohio Department of Natural Resources. The data were formatted with a county number, a county name, a LANDSAT category and an acreage figure. Only non-zero categories were on the tape. Thus, the first step in the analysis was to write a small program to fill in the zero acre categories. Following this, correlation and regression analyses were performed using SPSS. Data were input in the same form as for the tax models. Here, though, a LANDSAT category of land use, in acres, is the dependent variable, and population and employment data are the independent variables.

Results of the Macro Level and Modeling Tests

Table 69 is the list of variables used in the analysis. Table 67 shows the correlations among these variables. One way of analyzing the possibility of macro level errors is by comparing the correlations among the land use variables as defined by LANDSAT and those among land use variables as defined by tax categories. The tax category correlations are shown in Table 68. Here one can see that the correlations among LANDSAT categories is generally low. The highest coefficient is between urban center and urban residential (.56). All other correlations approach zero. In contrast, with the exception of agriculture, correlations among the tax categories were all above 0. 90. In general, one would expect a high degree of correlation among urban categories and a high correlation between urban and agricultural categories. Failure to show such correlation is an indicator of misclassification. Thus, this first statistical test of the LANDSAT data shows some potential problems with the data.

A second analysis was carried out using regression. Here, the dependent variable was always a LANDSAT category and the independent variables were employment and estimated population. These regression equations are of the same form as the tax models. If the LANDSAT data are accurate at the macro level, statistically significant regression equations should result. Table 70 shows these regression results. One can see that in general, the level of explanation of these models is very low (Adjusted R Square x 100%). The exception to this is for urban residential which has an R^2 value of .73. One surprising result is that agricultural then vegetation has a significant relationship with the socio-economic variables. Since these variables are all urban oriented employment, it would appear that there is significant misclassification of urban land into this agricultural category.

Table 67

Correlations Among LANDSAT Categories

Variables

	V03	V04	V05	V06	V07	V08	V09
V03	1.0						
V04	0.56						
V05	0.09	0.09	1.0				
V06	0.19	0.10	0.18	1.0			
V07	0.07	0.27	0.02	0.23	1.0		
V08	0.17	0.21	0.41	0.21	-0.14	1.0	
V09	0.01	0.38	-0.07	0.25	0.46	-0.30	1.0

Table 68

Correlations Among Tax Categories

	Agricultural	Industrial	Commercial	Residential
Agricultural	1.0			
Industrial	-0.09	1.0		
Commercial	-0.02	0.95	1.0	
Residential	-0.01	0.97	0.99	1.0

DOCUMENTATION FOR SPSS FILE 'NEW.NRST'

LIST OF THE 1 SUBFILES COMPRISING THE FILE

NEW.NRST N= 76

DOCUMENTATION FOR THE 39 VARIABLES IN THE FILE 'NEW.NRST'

REL POS	VARIABLE NAME	VARIABLE LABEL	MISSING VALUES	PRT FMT
1	SEQNUM		NONE	0
2	SUBFILE		NONE	A
3	CASWGT		NONE	4
4	V01	COUNTY NO	NONE	0
5	V02	COUNTY NAME	NONE	0
6	V03	ACRES URB CENTER	NONE	0
7	V04	ACRES URB RESIDENT	NONE	0
8	V05	URBAN RES RANGE	NONE	0
9	V06	AG THICK VEG	NONE	0
10	V07	AG THIN VEG	NONE	0
11	V08	AG BARE SOIL	NONE	0
12	V09	AG PASTURE	NONE	0
13	V10	RANGELAND URBAN	NONE	0
14	V11	RANGELANDSCRUBLAND	NONE	0
15	V12	RANGELAND MEADOWS	NONE	0
16	V13	RANGELAND GRASSLAND	NONE	0
17	V14	FOREST MIXED	NONE	0
18	V15	WATER TURBID	NONE	0
19	V16	WATER CLEAR	NONE	0

Table 69 List of Variables in Regression Analysis

DOCUMENTATION FOR THE 39 VARIABLES IN THE FILE 'NEW.NRST'

REL POS	VARIABLE NAME	VARIABLE LABEL	MISSING VALUES	PRT FMT
20	V17	WETLAND NONFORESTED	NONE	0
21	V18	WETLAND FORESTED	NONE	0
22	V19	BARREN BARE	NONE	0
23	V20	BARREN URBAN	NONE	0
24	V21	BARRFN QUARRY	NONE	0
25	V22	BARREN SAND	NONE	0
26	V23	BARREN SETTLING POND	NONE	0
27	V24	UNIDENTIFIED	NONE	0
28	V25	UNLISTED	NONE	0
29	V26	EST 1974 POP	999999.	0
30	V27	TOTAL EMPLOY	999999.	0
31	V28	MINING EMPLOY	999999.	0
32	V29	CONSTRUCTION EMPLOY	999999.	0
33	V30	MFG EMPLOY	999999.	0
34	V31	TRANS EMPLOY	999999.	0
35	V32	WHOLESALE EMPLOY	999999.	0
36	V33	FINANCE EMPLOY	999999.	0
37	V34	SERVICE EMPLOY	999999.	0
38	V35	GOVERNMENT EMPLOY	999999.	0
39	V36	CARD NO	999999.	0

Table 69 (cont.) List of Variables in Regression Analysis

FILE NEW.NRST (CREATION DATE = 05/28/77)

* M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * * VARIABLE LIST 1
REGRESSION LIST 1

DEPENDENT VARIABLE.. V03 ACRES URB CENTER

VARIABLE(S) ENTERED ON STEP NUMBER 1..

V26	EST 1974 POP
V27	TOTAL EMPLOY
V30	MFG EMPLOY
V31	TRANS EMPLOY
V32	WHOLESALE EMPLOY
V33	FINANCE EMPLOY
V34	SERVICE EMPLOY

MULTIPLE R	0.64559
R SQUARE	0.41676
ADJUSTED R SQUARE	0.32184
STANDARD ERROR	2122.20257

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	7.	138395459.91579	19770779.98797	4.38985
RESIDUAL	43.	193660980.59402	4503743.73474	

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	BETA	STD ERROR B	F
V26	0.00604	0.44992	0.02400	0.063
V27	0.07286	2.29703	0.35952	0.041
V30	-0.22324	-2.16154	0.31396	0.506
V31	-0.29765	-0.48606	0.68643	0.188
V32	0.81946	6.51014	0.60003	1.865
V33	-0.94677	-1.88763	0.92710	1.043
V34	-0.79258	-4.47841	0.54122	2.145
(CONSTANT)	778.59401			

------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F

ALL VARIABLES ARE IN THE EQUATION

Table 70 Regression results

ORIGINAL PAGE IS
OF POOR QUALITY

268

TEST O. LANDSAT DATA AT MACRO LEVEL WITH SOCIO/ECONOMIC DATA 05/31/77 PAGE 7

FILE NEW.NRST (CREATION DATE = 05/28/77)

* M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * *

DEPENDENT VARIABLE.. V03 ACRES URB CENTER

VARIABLE LIST 1
REGRESSION LIST 1

SUMMARY TABLE

VARIABLE		MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
V26	EST 1974 POP	0.41266	0.17029	0.17029	0.41266	0.00604	0.44992
V27	TOTAL EMPLOY	0.45199	0.20429	0.03401	0.39008	0.07286	2.29703
V30	MFG EMPLOY	0.55396	0.30687	0.10257	0.29184	-0.22324	-2.16154
V31	TRANS EMPLOY	0.56507	0.31931	0.01244	0.35865	-0.29765	-0.48606
V32	WHOLESALE EMPLOY	0.62182	0.38665	0.06735	0.42470	0.81946	6.51014
V33	FINANCE EMPLOY	0.62265	0.38770	0.00104	0.40619	-0.94677	-1.88763
V34	SERVICE EMPLOY	0.64559	0.41678	0.02909	0.41485	-0.79258	-4.47841
(CONSTANT)						778.59401	

Table 70 (cont.) Regression Results

* M U L T I P L E R E G R E S S I O N * * * * * * * * * * * * * *

VARIABLE LIST 1
REGRESSION LIST 2

DEPENDENT VARIABLE.. V04 ACRES URB RESIDENT

VARIABLE(S) ENTERED ON STEP NUMBER 1..

V26	EST 1974 POP
V27	TOTAL EMPLOY
V30	MFG EMPLOY
V31	TRANS EMPLOY
V32	WHOLESALE EMPLOY
V33	FINANCE EMPLOY
V34	SERVICE EMPLOY

MULTIPLE R	0.87728
R SQUARE	0.76963
ADJUSTED R SQUARE	0.73213
STANDARD ERROR	4091.41760

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	7.	2404747075.91867	343535296.55981	20.52219
RESIDUAL	43.	719807012.82643	16739697.97271	

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	BETA	STD ERROR B	F
V26	0.01211	0.29422	0.04626	0.069
V27	-0.19879	-2.04298	0.69313	0.082
V30	-0.31650	-1.00027	0.60528	0.274
V31	-2.56858	-1.36736	1.32338	3.767
V32	3.24370	8.40069	1.15680	7.863
V33	-2.44200	-1.58721	1.78737	1.867
V34	-1.19085	-2.19356	1.04343	1.303
(CONSTANT)	2805.94365			

------------------ VARIABLES NOT IN THE EQUATION ------------------

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F

ALL VARIABLES ARE IN THE EQUATION

3-155

Table 70 (cont.) Regression Results

ORIGINAL PAGE IS
OF POOR QUALITY

270

FILE NEW.NRST (CREATION DATE = 05/28/77)

* M U L T I P L E R E G R E S S I O N * * * * * * * * * * * * * * VARIABLE LIST 1
REGRESSION LIST 2

DEPENDENT VARIABLE.. V04 ACRES URB RESIDENT

SUMMARY TABLE

VARIABLE		MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
V26	EST 1974 POP	0.61371	0.37664	0.37664	0.61371	0.01211	0.29422
V27	TOTAL EMPLOY	0.64854	0.42060	0.04396	0.58717	-0.19879	-2.04298
V30	MFG EMPLOY	0.76158	0.58000	0.15940	0.46083	-0.31690	-1.00027
V31	TRANS EMPLOY	0.78486	0.61601	0.03601	0.54185	-2.56858	-1.36736
V32	WHOLESALE EMPLOY	0.87085	0.75838	0.14238	0.63211	3.24370	8.40069
V33	FINANCE EMPLOY	0.87330	0.76265	0.00427	0.59910	-2.44200	-1.58721
V34	SERVICE EMPLOY	0.87728	0.76963	0.00698	0.62397	-1.19085	-2.19356
(CONSTANT)						2805.94365	

Table 70 (cont.) Regression Results

275

* M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * *

VARIABLE LIST 1
REGRESSION LIST 3

DEPENDENT VARIABLE.. V06 AG THICK VEG

VARIABLE(S) ENTERED ON STEP NUMBER 1.. V26 EST 1974 POP
V27 TOTAL EMPLOY
V30 MFG EMPLOY
V31 TRANS EMPLOY
V32 WHOLESALE EMPLOY
V33 FINANCE EMPLOY
V34 SERVICE EMPLOY

MULTIPLE R	0.28846
R SQUARE	0.08321
ADJUSTED R SQUARE	-0.06603
STANDARD ERROR	20256.29864

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	7.	1601396530.61784	228770932.94541	0.55755
RESIDUAL	43.	17643658288.71549	410317634.62129	

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	BETA	STD ERROR B	F
V26	-0.09269	-0.90713	0.22904	0.164
V27	1.70316	7.05275	3.43162	0.246
V30	-2.02330	-2.57332	2.99671	0.456
V31	1.17673	0.25241	6.55197	0.032
V32	3.13691	3.27348	5.72723	0.300
V33	-6.84823	-1.79349	8.84912	0.599
V34	-7.55265	-5.60567	5.16592	2.137
(CONSTANT)	21945.89703			

------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F

ALL VARIABLES ARE IN THE EQUATION

Table 70 (cont.) Regression Results

ORIGINAL PAGE IS
OF POOR QUALITY

272

* M U L T I P L E R E G R E S S I O N * * * * * * * * * * * * * *

DEPENDENT VARIABLE.. V06 AG THICK VEG

VARIABLE LIST 1
REGRESSION LIST 3

SUMMARY TABLE

VARIABLE		MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
V26	EST 1974 POP	0.12240	0.01498	0.01498	-0.12240	-0.09269	-0.90713
V27	TOTAL EMPLOY	0.12338	0.01522	0.00024	-0.12336	1.70316	7.05275
V30	MFG EMPLOY	0.16549	0.02739	0.01216	-0.14854	-2.02330	-2.57332
V31	TRANS EMPLOY	0.16909	0.02859	0.00120	-0.12515	1.17673	0.25241
V32	WHOLESALE EMPLOY	0.19399	0.03763	0.00904	-0.11037	3.13691	3.27348
V33	FINANCE EMPLOY	0.19401	0.03764	0.00000	-0.10172	-6.84823	-1.79349
V34	SERVICE EMPLOY	0.28846	0.08321	0.04557	-0.11959	-7.55265	-5.60567
(CONSTANT)						21945.89703	

Table 70 (cont.) Regression Results

273

* M U L T I P L E R E G R E S S I O N * * * * * * * * * * * * * *

VARIABLE LIST 1
REGRESSION LIST 4

DEPENDENT VARIABLE.. V07 AG THIN VEG

VARIABLE(S) ENTERED ON STEP NUMBER 1..

V26	EST 1974 POP
V27	TOTAL EMPLOY
V30	MFG EMPLOY
V31	TRANS EMPLOY
V32	WHOLESALE EMPLOY
V33	FINANCE EMPLOY
V34	SERVICE EMPLOY

MULTIPLE R	0.62057
R SQUARE	0.38510
ADJUSTED R SQUARE	0.26500
STANDARD ERROR	50342.24170

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	7.	68251189088.64470	9750169869.80639	3.84722
RESIDUAL	43.	108976675885.35529	2534341299.65943	

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	BETA	STD ERROR B	F
V26	1.33172	4.29502	0.56922	5.473
V27	-15.57252	-21.24980	8.52848	3.334
V30	12.44520	5.21592	7.44762	2.792
V31	7.25096	0.51252	16.28336	0.198
V32	48.10925	16.54362	14.23368	11.424
V33	29.60955	2.55533	21.99239	1.813
V34	-30.48836	-7.45686	12.83868	5.639
(CONSTANT)	84047.41950			

------------------ VARIABLES NOT IN THE EQUATION ------------------

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F

ALL VARIABLES ARE IN THE EQUATION

Table 70 (cont.) Regression Results

FILE NEW.NRST (CREATION DATE = 05/28/77)

* M U L T I P L E R E G R E S S I O N * * * * * * * * * * * * * * VARIABLE LIST 1
REGRESSION LIST 4

DEPENDENT VARIABLE.. V07 AG THIN VEG

SUMMARY TABLE

VARIABLE		MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
V26	EST 1974 POP	0.10361	0.01073	0.01073	0.10361	1.33172	4.29502
V27	TOTAL EMPLOY	0.31114	0.09681	0.08608	0.07099	-15.57252	-21.24980
V30	MFG EMPLOY	0.32934	0.10846	0.01165	0.10133	12.44520	5.21592
V31	TRANS EMPLOY	0.37541	0.14093	0.03247	0.02436	7.25096	0.51252
V32	WHOLESALE EMPLOY	0.40740	0.16597	0.02504	0.06916	48.10925	16.54362
V33	FINANCE EMPLOY	0.55178	0.30446	0.13849	0.03714	29.60955	2.55533
V34	SERVICE EMPLOY	0.62057	0.38510	0.08064	0.04445	-30.48836	-7.45686
(CONSTANT)						84047.41950	

Table 70 (cont.) Regression Results

275

Conclusions

A number of conclusions can be drawn with regard to the use of LANDSAT data in socio-economic, land use modeling. These are as follows:

1) Significant, substantial misclassification and misalignment problems occur at the micro scale.

2) Significant misclassification errors occur at the macro scale.

3) Results indicate that the LANDSAT data for Ohio are not of high enough accuracy to be used in a modeling framework. These results apply only to these data. Similar tests of errors are needed using other data in different areas with different interpretation methods than those used by Bendix Corporation.

4) One category of LANDSAT (Urban Residential) does form a significant relationship with the socio-economic data. This indicates that a more accurate LANDSAT data base in the future could lead to a set of simulation models of the same type as the tax models. Accuracy in all categories would need to go above 90% in order for such models to be reasonably accurate and useful.

Recommendations

A number of recommendations can be made as a result of the three stages of this research. These can be summarized as follows:

1) The project developed several models of property tax base which were programmed for use by the Department of Economic and Community Development. Use of these products should be made whenever possible.

2) More testing needs to be done on the micro and macro level errors associated with LANDSAT interpretations. Testing should follow the methodologies developed in this study in order to quantify, in a comparable manner, the errors associated with LANDSAT, and to improve interpretation technologies. Comparisons should be made of different interpretation techniques in various geographic areas.

3) Given an improvement in interpretation accuracy (to approximately 90% correct), additional effort should be expended to estimate and verify LANDSAT based socio-economic, land use models for Ohio in a form comparable to the tax models.

FINAL REPORT ON

DEVELOPMENT OF A MULTI-DISCIPLINARY ERTS USER PROGRAM

IN THE STATE OF OHIO

Volume 4

DEVELOPMENT OF NEW APPLICATIONS

OHIO DEPARTMENT OF
ECONOMIC AND COMMUNITY
DEVELOPMENT

277

Volume 4

DEVELOPMENT OF NEW APPLICATIONS

FINAL REPORT:	Development of a Multi-Disciplinary ERTS User Program in the State of Ohio
PERFORMED FOR:	Goddard Space Flight Center
CONTRACT NUMBER:	NAS5-22399
DATE:	September 5, 1977
PRINCIPAL INVESTIGATOR:	Paul E. Baldridge Assistant Director Department of Economic and Community Development P.O. Box 1001 Columbus, Ohio 43216
PROGRAM MANAGER:	Thomas A. Martin Program Manager Remote Sensing Programs Department of Economic and Community Development
INVESTIGATORS:	Volume Four
	Battelle Columbus Laboratories Mr. G. E. Wukelic Mr. J. G. Stephan Mr. T. F. Ebbert Mr. H. E. Smail

279

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

283

LIST OF FIGURES

LIST OF FIGURES
(Continued)

285

LIST OF FIGURES
(Continued)

INTRODUCTION

This volume reports the work on Development of New Applications of LANDSAT technology. Initial cooperative research efforts among NASA, the State Government of Ohio and Battelle's Columbus Laboratories between 1972 and 1974 demonstrated technical feasibility of using LANDSAT acquired data in various land use planning resource management and environmental programs.

The follow-on LANDSAT 2 program involved work to develop new application possibilities and promotion of user awareness. Building on its past involvement, Battelle was given the responsibility to work in this third element of the State LANDSAT follow-on program.

OVERALL PROJECT OBJECTIVE, SCOPE AND RESEARCH PLAN

The overall objective of the Battelle project in support of the NASA-Ohio LANDSAT follow-on program was to assist in the technical development of practical methods for routinely using LANDSAT data in Ohio. The Battelle responsibilities actually included functional objectives under two major project activities: (1) new application analyses and (2) user awareness activities.

Most of the project effort related to evaluating new application possibilities for using LANDSAT-type data for economic, resource and community development interests in Ohio. Actually, four explicit research tasks were undertaken. Two of the tasks had economic and resource development significance and involved the analysis/evaluation of LANDSAT and high-altitude aerial data for oil/gas exploration use and woodland surveys in the State. Another of the tasks emphasized the development of procedures for

improving LANDSAT data use in urban land use planning applications. The fourth task involved a preliminary assessment of the feasibility of using repetitive LANDSAT data for monitoring/modeling sedimentation dynamics in Lake Erie. The overall research plan for undertaking the four specific evaluation tasks showing the role of Battelle and the Ohio Department of Economic and Community Development is shown in Figure 1.

The scope of the remaining project effort related to user awareness activities and involved primarily staff interactions between Battelle and potential user personnel.

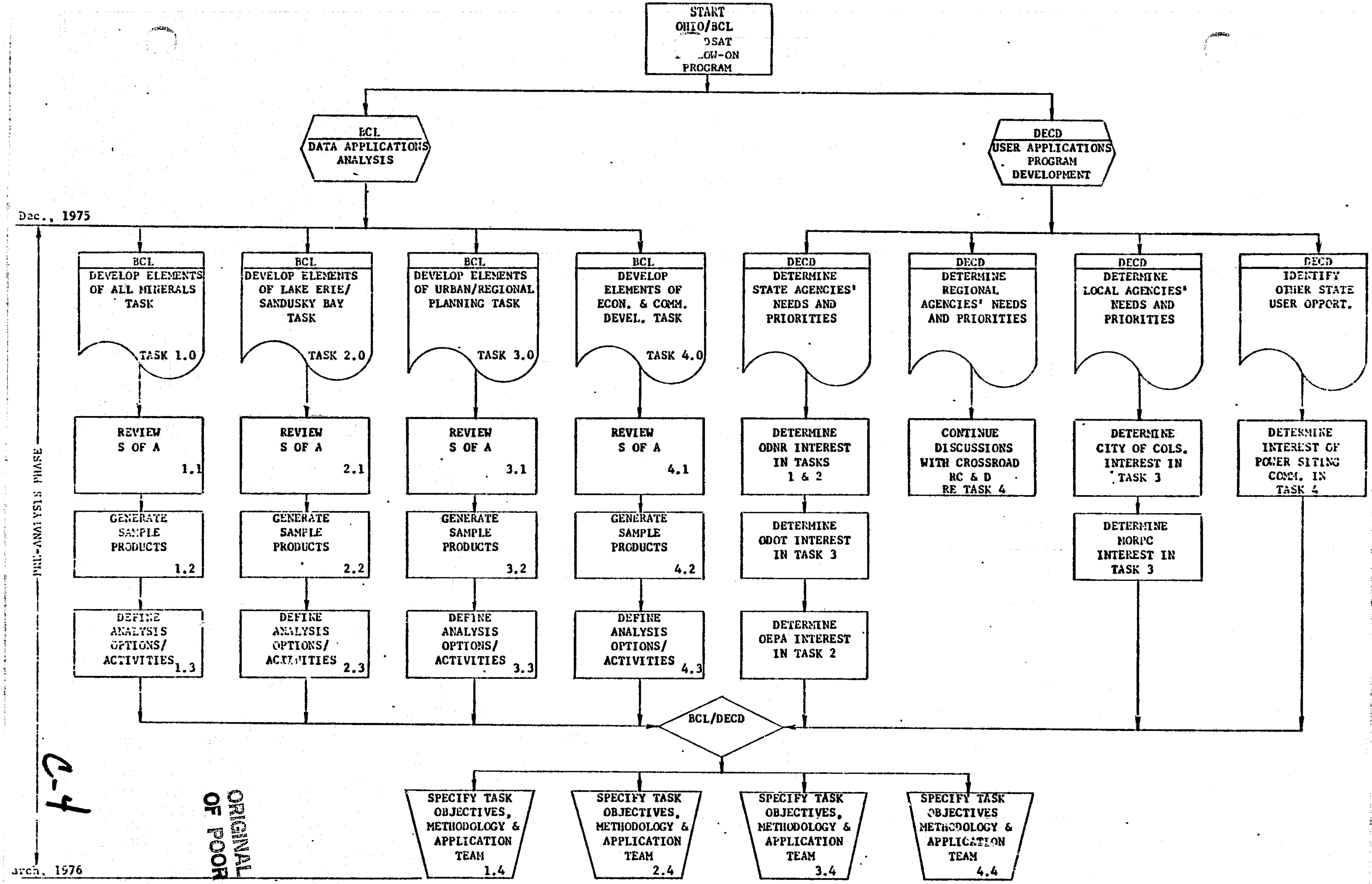
PRINCIPAL DATA SOURCES

The principal data which were available and analyzed for the different LANDSAT study tasks are shown in the matrix in Table 1. Other information and data used were in the form of documents and reference material containing, in several cases, as in the sedimentation task, actual field survey measurements.

TABLE 1. PRINCIPAL DATA AVAILABLE AND ANALYZED

Task Identification	LANDSAT Imagery	LANDSAT CCT Tapes	Skylab Imagery	High-Altitude A/C	Low-Level A/C	Ground Truth
1. Linear Analysis	x		x	x		
2. Lake Erie Sedimentation	x					
3. Urban Land Use	x	x		x	x	x
4. Woodland Analysis	x		x	x	x	x

Initially proposed study areas where NASA overflight data were required are shown in Figure 2. Extremely high-quality NASA aerial color IR imagery was provided and most effectively utilized in the Columbus/



C-4

ORIGINAL PAGE IS OF POOR QUALITY

FIGURE 1. DELTA CHART FOR OHIO/BCL FOLLOW-ON LANDSAT PROGRAM

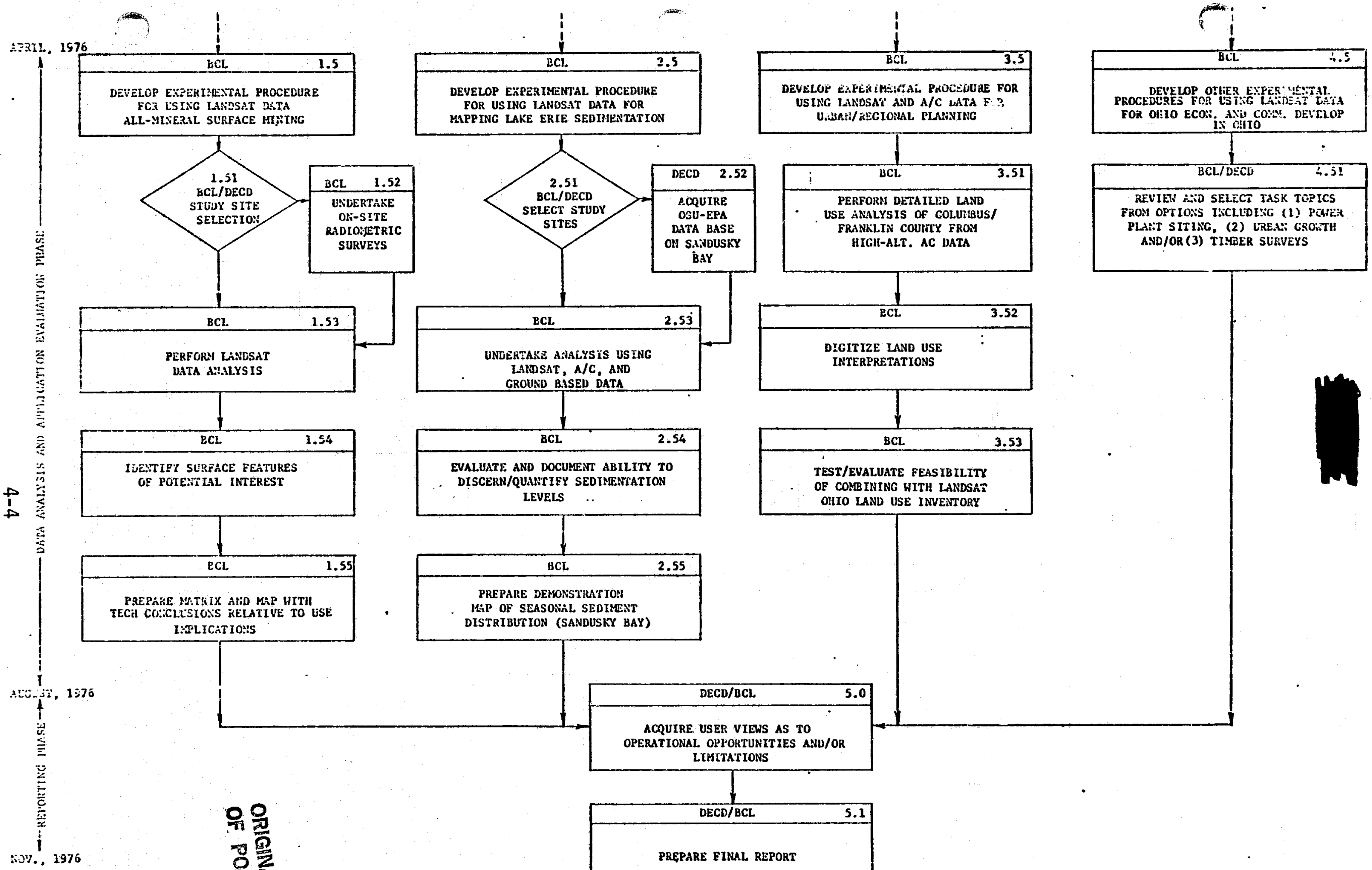


FIGURE 1. (Continued)

290

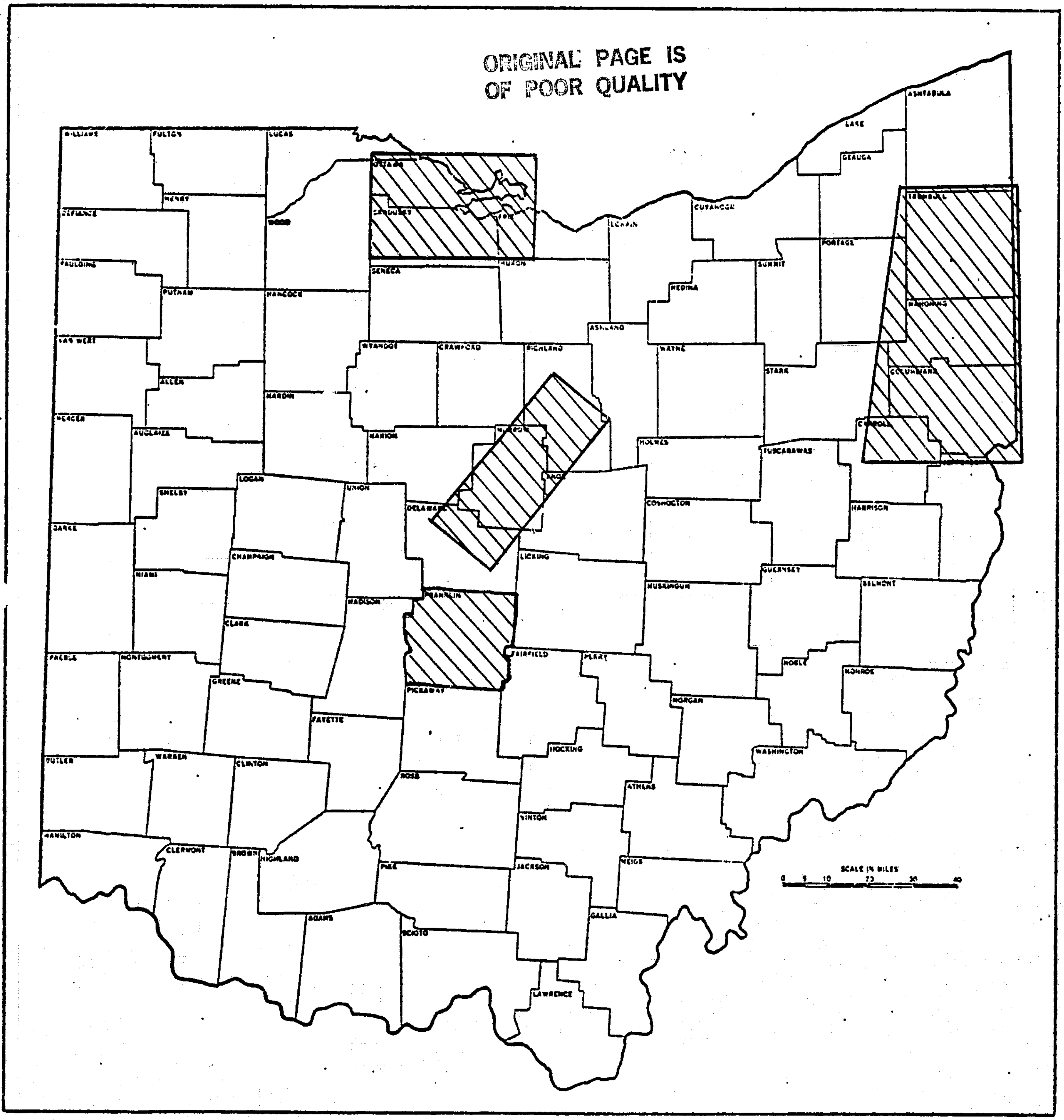


FIGURE 2. PROPOSED OHIO LANDSAT 2 STUDY AREAS

(NASA Aircraft CIR photographic coverage obtained on August 18, 1975, and/or May 22, 1976.)

Franklin County urban land use study. In other tasks, such as the Northeast Ohio woodland survey, the low quality and late arrival of aircraft imagery restricted its effective use. In general, the following factors limited the use of the high-altitude aircraft data:

(1) Acquisition and receipt of overflight data were too late in the program to provide adequate time for meaningful analysis

(2) Weather conditions over some of the study areas were poor and the imagery acquired was of very low quality

(3) Camera settings appeared to have been preselected for study sites in areas other than in Ohio, resulting in incorrectly exposed film

(4) Vignetting was present on all film received.

SUMMARY OF PROJECT RESULTS AND APPLICATION IMPLICATIONS

A pictorial synopsis of each of the major LANDSAT follow-on tasks undertaken by Battelle is presented in Figures 3 through 6. These figures show the data base, the analysis methods, and the major results associated with each of the data application tasks. In brief, the linear mapping and the urban land use analysis studies were the more successful efforts, and the results are of potential major relevance to subsequent efforts to use LANDSAT data operationally in Ohio. The other LANDSAT data application studies were not as positive, and will require more research before operational use can be recommended. A brief summary of the significant results and application implications for each study follows.

Ohio LANDSAT Imagery Linear Analysis

This task was both timely, in terms of current Ohio needs and interests in increasing oil and natural gas production in the area, and significant in terms of the positive results obtained. The task clearly demonstrated how linear and curvilinear features of potential significance for oil and gas exploration activities in Ohio and surrounding areas can be identified and mapped using small-scale LANDSAT imagery and unsophisticated photo-interpretation techniques.

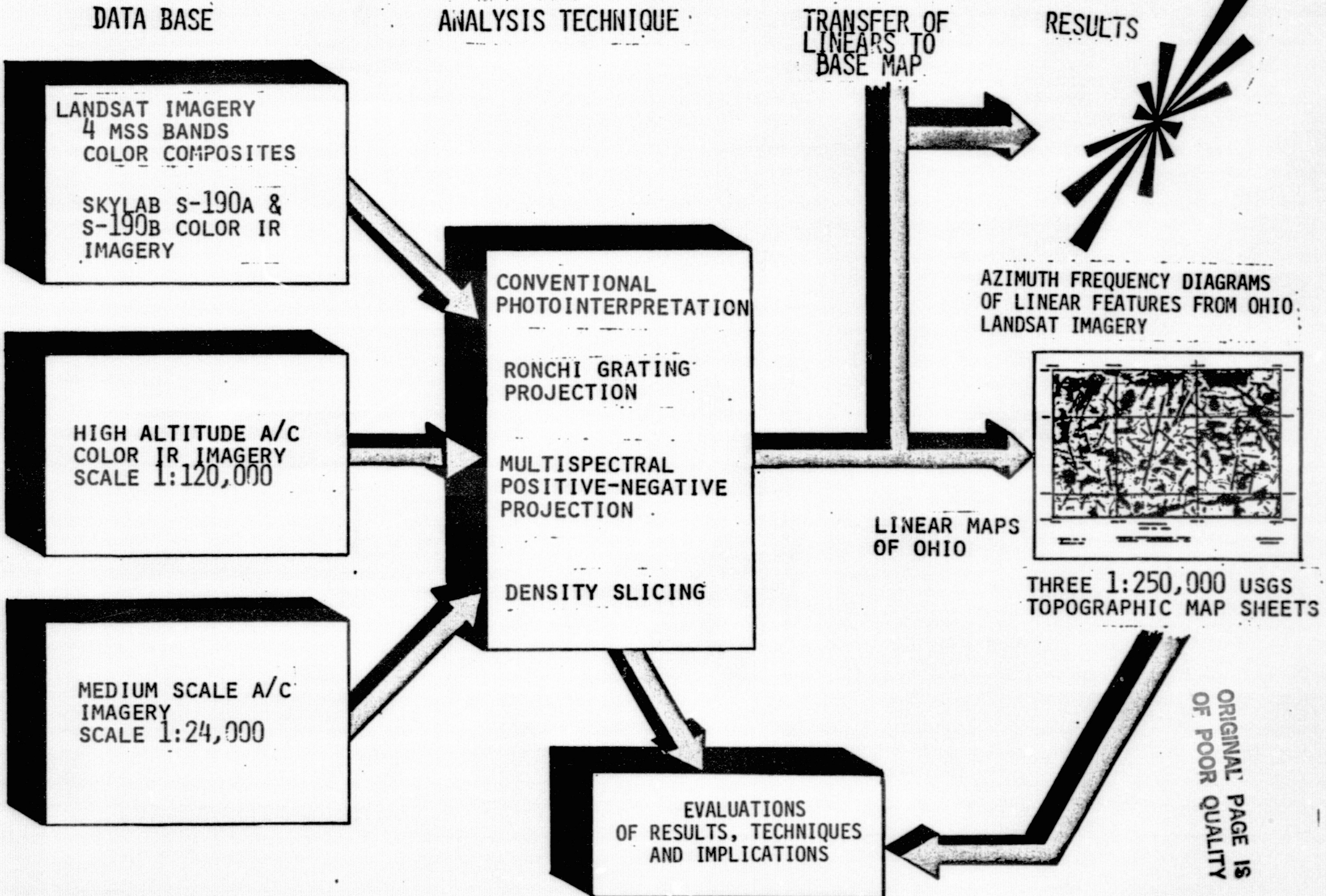


FIGURE 3. OHIO LANDSAT IMAGERY LINEAR ANALYSIS

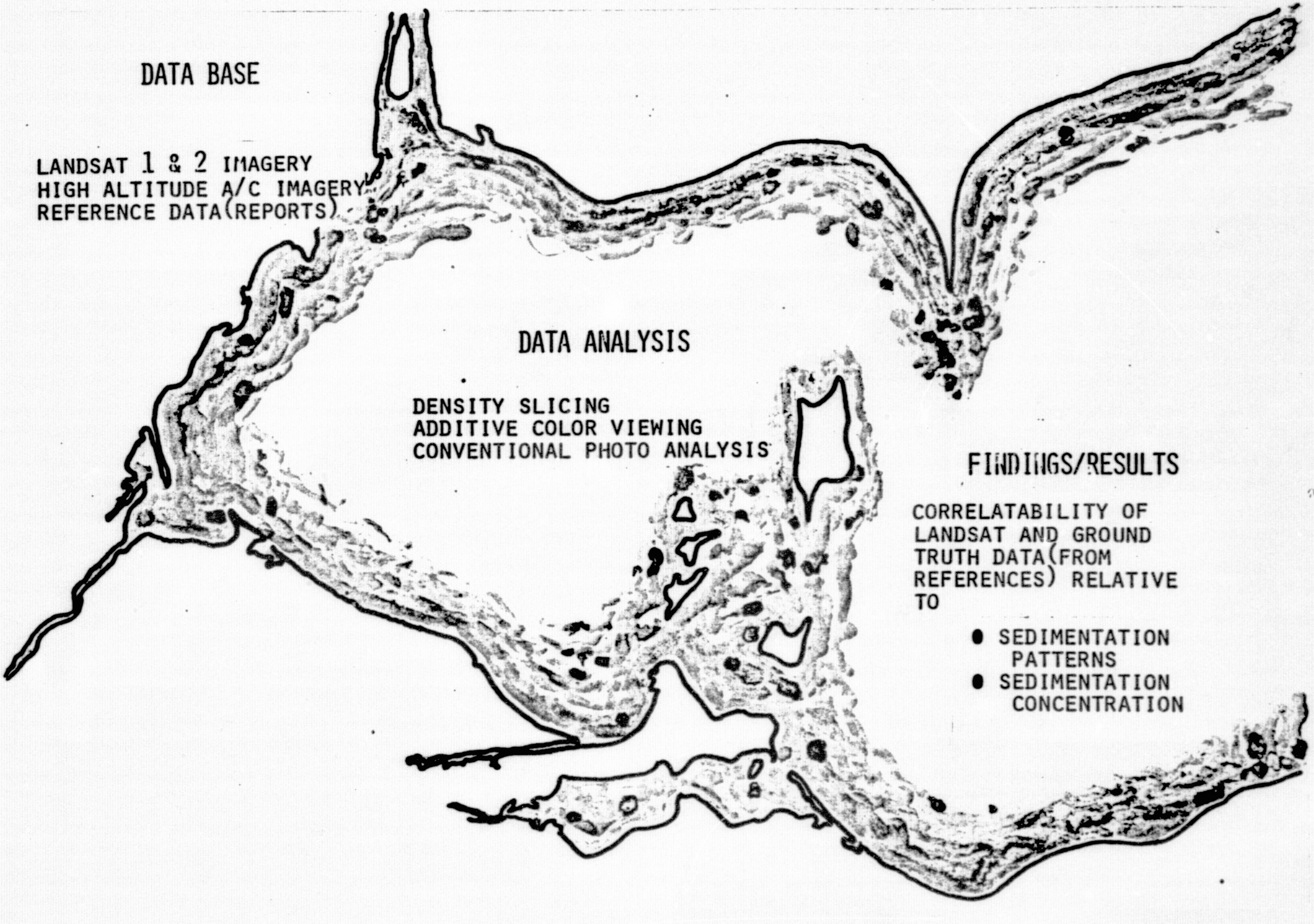


FIGURE 4. LANDSAT LAKE ERIE SEDIMENTATION STUDY

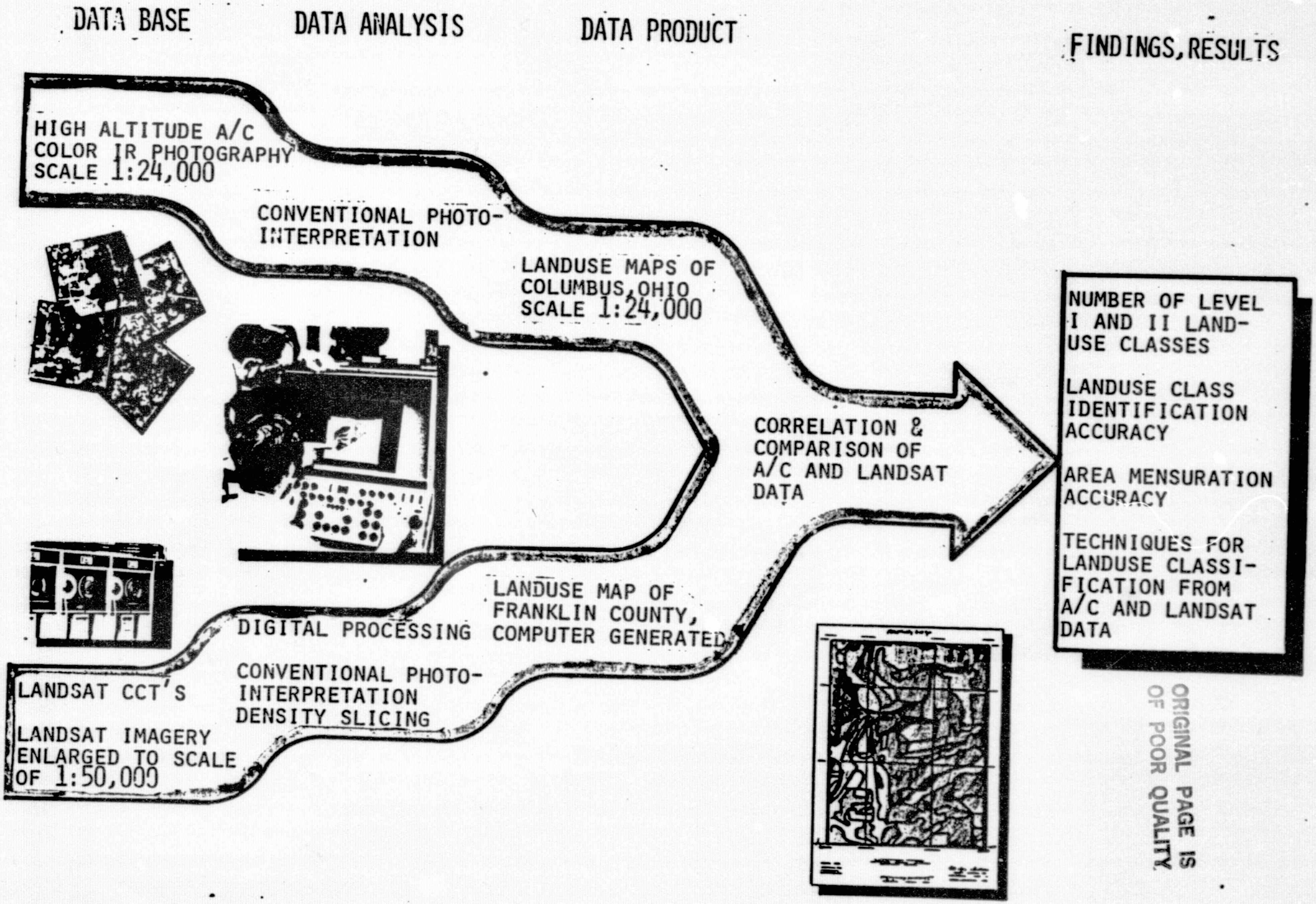


FIGURE 5. LANDSAT AND AIRCRAFT LAND USE ANALYSIS OF COLUMBUS/FRANKLIN COUNTY, OHIO AREA

DATA BASE

DATA ANALYSIS

FINDINGS/RESULTS

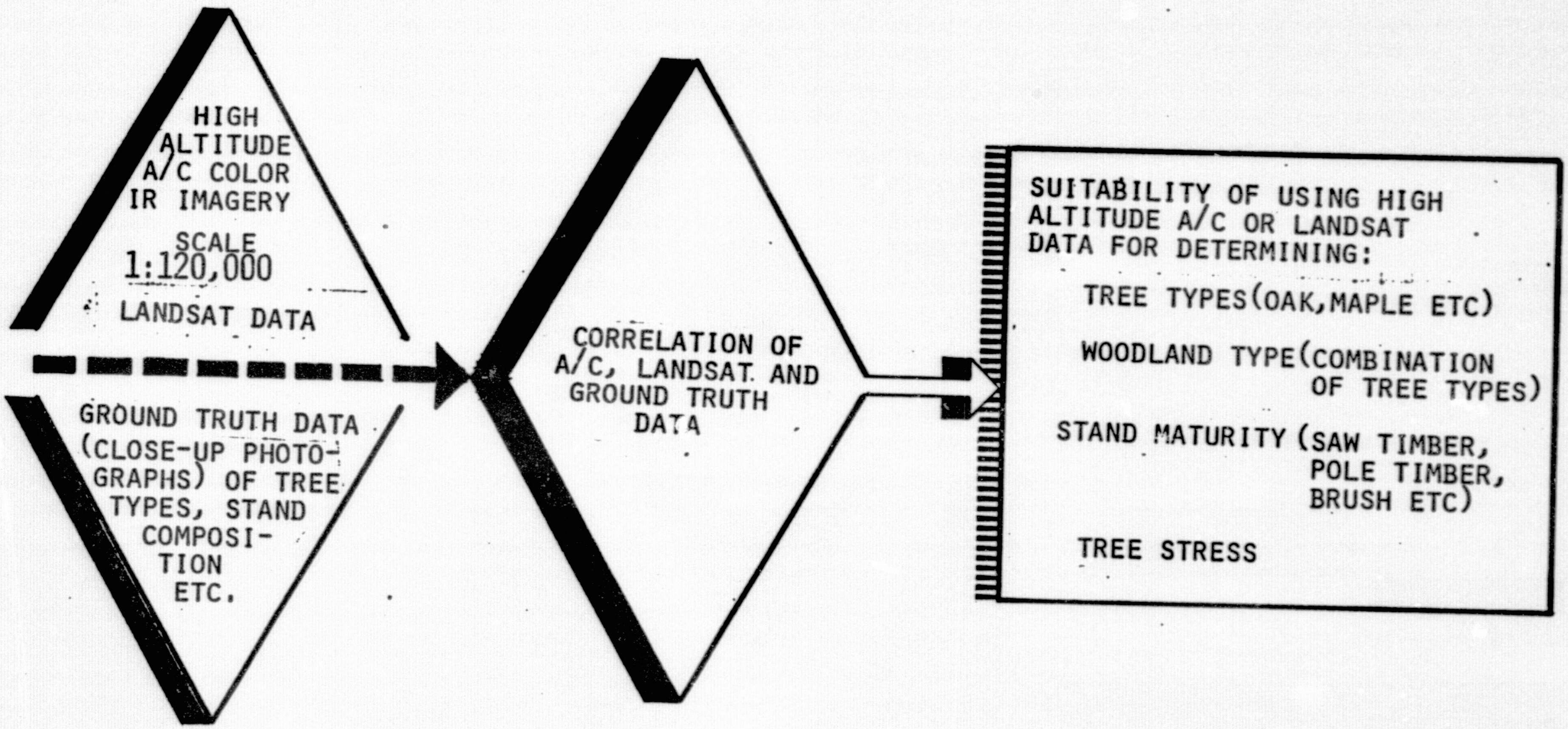


FIGURE 6. NORTHEAST OHIO/TRUMBULL COUNTY WOODLAND INVENTORY STUDY

A preliminary correlation of mapped LANDSAT linears of approximately two-thirds of Ohio showing dominant linear trends (length and direction) with established geological and geophysical trends was quite positive, resulting in the following principal conclusions:

- Conventional LANDSAT imagery is more responsive to regional-sized linear identification and mapping than is aircraft imagery. The lower resolution of current LANDSAT imagery ($\approx$ 80 meters) is well suited for large area analysis and, in fact, actually obscures roads and other cultural features often misinterpreted as linears on high-resolution imagery. However, for very localized (large scale) linear analysis, increased resolution of LANDSAT imagery or the use of high-altitude aircraft data is required.
- Over 600 LANDSAT linear features of Ohio have been identified and mapped which are considered to be potentially geologically significant and should encourage commercial exploratory investigation, which may result in increased resource discovery.
- If, when field checked, Ohio LANDSAT lineations correlate with joint patterns, the probability of fracture-enhanced reservoirs in the trend of the lineations of production significance will be established.
- LANDSAT-derived lineations represent new investigative evidence which, when coupled with conventional exploration tools, could <u>inexpensively</u> <u>increase</u> the discovery rate of oil, gas, and other minerals in Ohio.

Federal and State Government personnel and independent Ohio oil and gas operators contacted during this study are optimistic relative to the potential of using LANDSAT imagery for mapping geological linears in Ohio and surrounding Appalachia areas, and recommended (1) the systematic preparation of first-generation (experimental) LANDSAT linear maps and atlases for public distribution and use, (2) additional effort to improve and standardize the linear analysis and mapping techniques, and (3) more analysis and field work to verify and document the feasibility of using LANDSAT data operationally for linear analysis in the Appalachia region.

<u>LANDSAT Lake Erie Sedimentation Analysis</u>

This task set out to demonstrate that repetitive, multi-spectral LANDSAT data could be effectively used to identify, measure, and model

changes in sediment loading in Lake Erie. Unfortunately, anticipated on-the-lake measurements of sedimentation commensurate with LANDSAT overpasses planned by other Lake Erie researchers were not obtained, necessitating that ground truth data collected at a water quality monitoring station on a tributary of Lake Erie be used in the correlative analysis. Consequently, differences in Lake Erie sediment loading derived from LANDSAT imagery analysis and that measured directly in the tributary of Lake Erie during LANDSAT overpasses could not be effectively explained. Therefore, even though some good agreements were found for the 1973-1976 analysis period, the results for other periods were too variable to justify any final conclusion regarding the operational potential of such a technique. However, additional and more extensive research efforts should clarify uncertainties noted in this brief analysis and result in the development of a methodology for operational use.

LANDSAT and Aircraft Urban Land Use Analysis of Columbus/ Franklin County, Ohio

Much concern exists nationally as to the potential of using computer-processed LANDSAT data for inventorying and mapping land uses, particularly in regions experiencing significant development or change such as urban areas. Findings to date have represented two extremes. Some investigators tend to overstate the LANDSAT data use potential, while others are overcritical of the detail and accuracy limitations of current LANDSAT data use. The State of Ohio is in the process of generating a state-wide land use inventory based on computer-processed LANDSAT data. This task was established to experimentally assess the opportunities and limitations of using such data operationally, particularly for the larger, complex metropolitan areas.

An overview of the data analysis procedures and results of this task, which basically compared high-altitude aerial and LANDSAT data, is shown in Figure 5. In brief, the state user-personnel want to know whether they can implement the operational use of computer-processed LANDSAT data. The results of this correlative analysis suggest that the LANDSAT land use inventory can be effectively and confidently utilized in nonurban areas and for selected planning interests (such as for new growth trends) in the

larger urbanized areas. Further, to meet the more detailed needs of land use planners and state decision-makers, it is practical and expedient to incorporate digitized results of aerial photointerpretation of selected land use classes for the more dynamic metropolitan areas in Ohio. In all cases, an attempt should be made to prepare color-coded land use outputs for end-user distribution rather than conventional black and white alphanumeric computer printouts, which are difficult to use.

Woodland Survey of Northeastern Ohio

Prior research had demonstrated that economical and accurate inventories of total forestland in Ohio using Skylab and LANDSAT data were feasible. However, planners involved in the development of the timber industry in Northeastern Ohio need more detailed information about the type and condition of timber stands before such remote sensing data can be used routinely. Accordingly, this task set out to determine if high-altitude aerial color infrared imagery could provide the needed detailed information. Figure 6 shows an overview of the task.

Emphasis was placed on delineating woodland boundaries, stand composition, stand maturity, cut and reseeded areas and tree stress due to grapevine infestation. Sample forest areas in Trumbull, Mahoning and Franklin Counties were selected to provide representative forest areas of predominantly oak, maple, and pine stands. Conventional techniques were applied to determine forest parameter detail, such as tree height, crown diameter, etc. Machine aided techniques were also explored to determine the feasibility of using computerized processing techniques. It was found that the high altitude aircraft imagery is suitable for delineating most pertinent forest parameters. The possibility of using temporal LANDSAT MSS data in conjunction with high-altitude aircraft and ground truth data was also investigated. The result of this effort suggests that it may be feasible to perform detailed computerized forest inventories of Ohio forestlands, provided such inventories are made in concert with extensive aircraft and ground truth data.

TASK 1. OHIO LANDSAT IMAGERY LINEAR ANALYSIS

TASK 1. OHIO LANDSAT IMAGERY LINEAR ANALYSIS

Background

In the initial plans for follow-on LANDSAT investigations in Ohio, consideration was given to evaluating/demonstrating the potential of using LANDSAT data for resource discovery (all minerals) interests in Ohio. The plan was to identify from surface spectral signatures possible mineral sites (e.g., sand, ground, limestone, etc.) of exploration interest. However, because of the recent and critical need to increase oil and natural gas production in the Eastern United States in general and specifically in Ohio, this task was confined to demonstrating the feasibility of using LANDSAT data for identifying structural linears of potential oil and gas exploration significance.

Joints and fracture systems in rock strata are potential reservoir locations for accumulated oil and gas. These systems may result from lateral tension or compression geologic forces applied to the rock strata and can also result from differential rebound of the Earth's crust after the removal of vertical and shear ice loads as developed from continental glaciation.

Joints and fractures can manifest themselves as linear or curvilinear features on the Earth's surface and appear on aerial imagery as photolinears. Much of the work done in the past has been accomplished utilizing aerial photography for linear analysis. The scale of these data is such that each image covers only a limited localized area, thus making the mapping of extensive, subtle, regional linears within a large area very difficult. Each LANDSAT image, on the other hand, covers an area of 34,000 square kilometers, providing the regional view needed to rapidly survey linear features over a large area with minimum scale distortion.

Objective and Scope

The task plan was to identify and plot linear and curvilinear features over a large portion of Ohio utilizing LANDSAT imagery. This was to be accomplished utilizing currently accepted (conventional) analysis

procedures. It was also planned to identify other interpretive methods which could be effectively utilized in identifying linears. Primarily, LANDSAT color composites and black and white imagery were to be evaluated. Skylab and high-altitude aircraft images were also to be briefly analyzed for purposes of comparison. Field verification providing ground truth for the identified linears was not a part of the planned program.

Three 9 by 9-in. LANDSAT color composite transparencies at a scale of 1:1,000,000, covering a large portion of the State of Ohio and portions of adjacent states, were examined to identify linear and curvilinear features (Figure 7). These scenes are as follows:

South Central Ohio	E1228 15431	8 March 73
Central Ohio	E1228 15424	8 March 73
West Central Ohio	E1605 15312	20 March 74.

The scenes were chosen on the basis of cloud-free and varied geomorphic conditions. The image dates were chosen to occur in the early spring, due to the lack of foliage and vigorous vegetation, thus presenting a better view of the geomorphic features. All three above listed areas contain oil and gas fields.

Methodology

Two methods, both manual, were utilized primarily in the interpretation of the imagery. The unaided eye was the first method used. The photointerpreter scanned the imagery to identify features which appeared to be aligned with one another on straight line features, circular anomalies and curvilinear features. The second method utilized a diffraction grating of 200 lines per in. The grating was held by hand, at about 8 to 12 in. from the image, near the interpreter's eye, and rotated very slowly 360 deg in the same plane as the image. Features which were aligned formed an enhanced or intensified straight line when at right angles to the rulings.

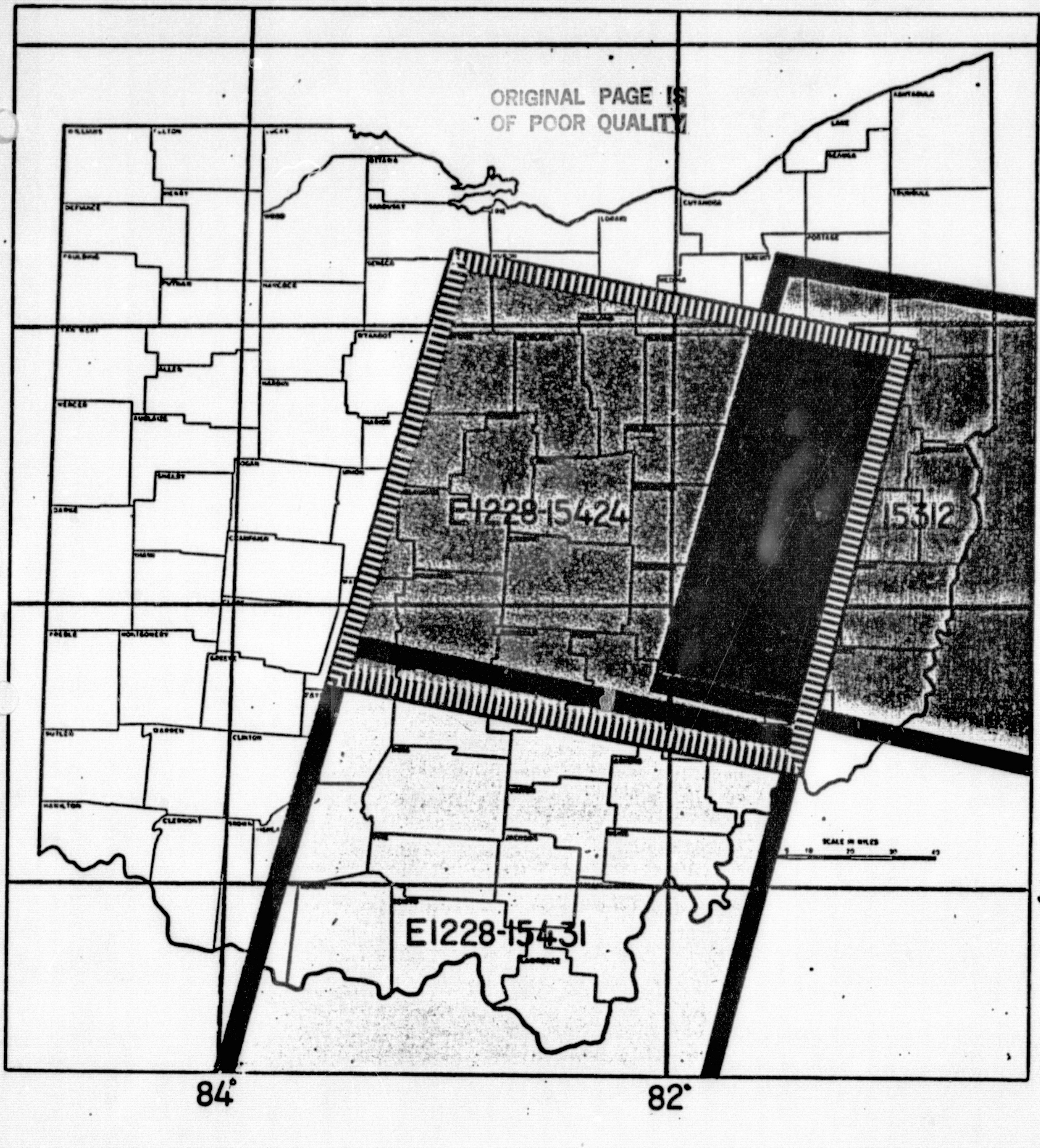


FIGURE 7. MAP SHOWING THE PORTION OF OHIO AND SURROUNDING AREAS COVERED BY LANDSAT LINEAR MAPPING TASK

Features which were continuous and linear were also enhanced when at right angles to the rulings. Circular anomalies and curvilinear features were best recognized using the unaided eye method; however, some circular anomalies were identified using the diffraction grating on a LANDSAT frame other than the frames used in this study. Inspection was made of an area containing a heavy concentration of linearly oriented ridges and valleys. The grating tended to subdue the visual prominence of these structures and allowed a clearer view of circular features which were obscured by the structural linearity of the area. The features appeared as short linears moving tangentially to and along the curve as the grating was rotated.

Each photo transparency was covered with clear plastic overlay material, and tick marks were drawn on the overlay to correspond with the photo registration marks. With the photos attached to a light box, the interpreter proceeded, using the unaided eye method, to scan the photos for: linear features, features which although segmented presented themselves in an aligned pattern, circular anomalies and curvilinear features. The features were plotted on the overlays for all three LANDSAT images. The interpreter then replaced the overlays with clean ones, again plotted the registration marks, and then using the 1-in.-square 200 line per in. Ronchi ruling (diffraction grating) proceeded to inspect each image again for the features. A method was devised for mounting the grating on a tripod while still retaining the ability to rotate the grating 360 deg. The grating was rotated and stopped at very short intervals throughout 360 deg. (Each linear is repeated twice in 360 deg, there being two times when the rulings and the linear are at right angles.) At every stop the interpreter plotted all linears visible. This step was repeated numerous times until the interpreter felt that he had plotted all linears.

These overlays were then removed, and each was registered with the complementary overlay produced by the unaided eye method. The next step involved placing each linear overlay in a projector system. Each was projected onto 1:250,000-scale topographic sheets. The linears for each photo and map area were then plotted on the maps. Linears which were identified by the unaided eye method only were annotated in blue. Linears which were identified using both methods were annotated in red and those identified

by diffraction grating alone were plotted in black. These three overlays are shown separately for each scene in the Results section of this report. The oil and gas fields which are plotted on the toposheets were outlined on the maps using colored tape. The borders of these were estimated.

Results

A large number of linears were identified using both the unaided eye and the diffraction grating methods (approximately 600 for 3 images). Figures 8a, 9a, and 10a show linears identified with the unaided eye for the three LANDSAT scenes analyzed. Figures 8b, 9b, and 10b show the results of the diffraction grating analysis for the same three scenes. The total linears identified using both methods are shown in Figures 8c, 9c, and 10c.

A larger number of linears were consistently identified using the diffraction grating method. Linears or portions of linears identified by both techniques were not as numerous as anticipated, implying that the unaided eye tends to recognize subtle and topographic features not discernible using the diffraction grating.

Numerous linears align with streams, valleys and ridges, as expected. Some also match with short segments of secondary highways, but these highways are not visible without magnification of the imagery, indicating that the linears are probably a result of natural features instead of the highways.

On inspection of the 1:250,000-scale maps*, it was found that there appears to be a NE-SW and a NW-SE linear trend in the area. A sample computerized linear trend analysis (rose pattern) was done for Scene E1228-15431 8 March 73. Figure 11a illustrates the normalized number of linears for each 5-deg sector. This figure clearly shows a NE-SW and a SSE-NNW trend for the area. Figure 11b shows the normalized summed lengths of linears per 5-deg sector. This pattern reflects not only a NE-SW and a SSE-NNW trend but also a ESE-WNW trend for the longer linears.

---

* Original 1:250,000-scale linear maps were transmitted to the State of Ohio.

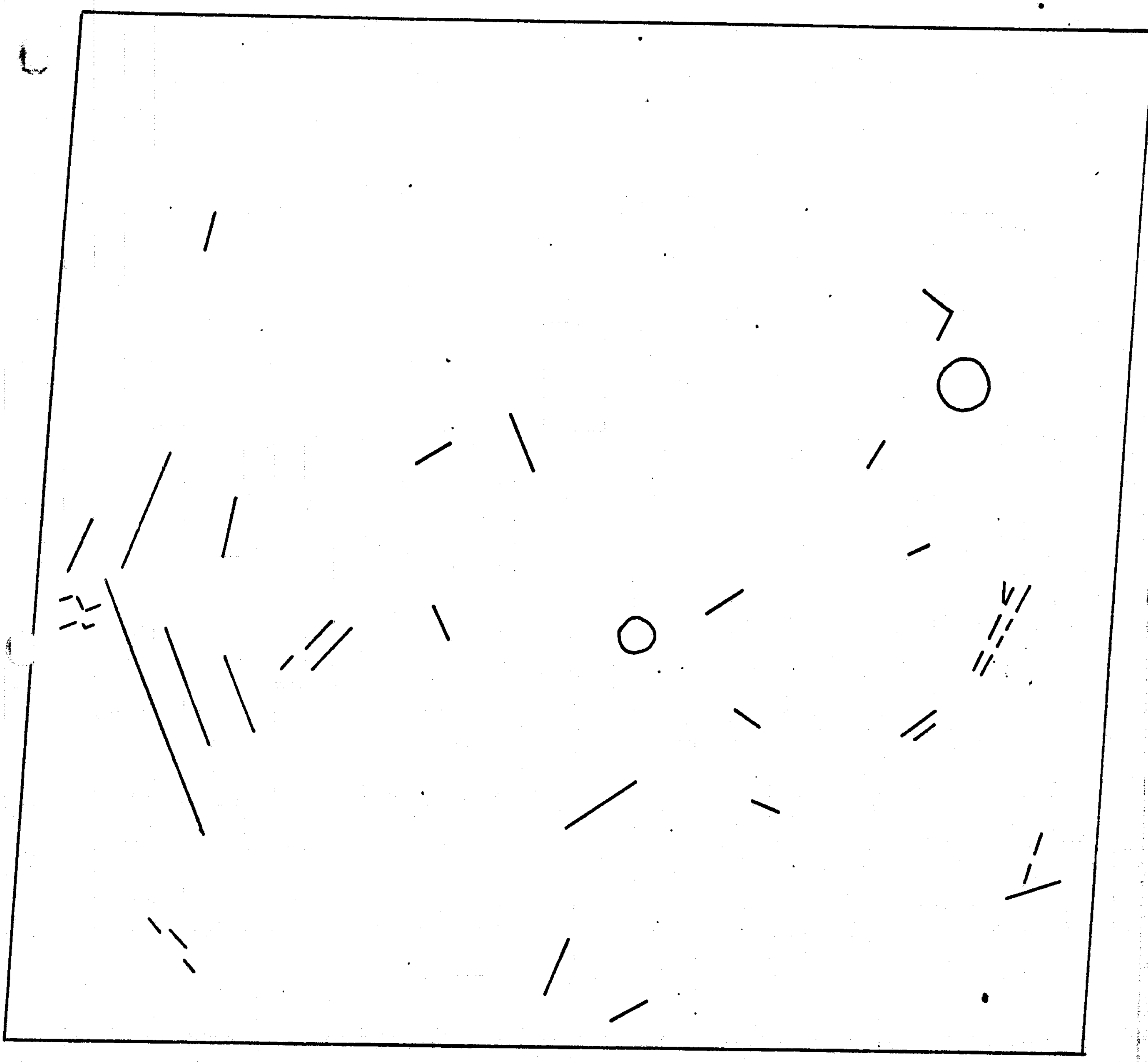


FIGURE 8a. LINEAR ANALYSIS OF SCENE E1228-15424 8 Mar 73
SHOWING UNAIDED EYE METHOD RESULTS

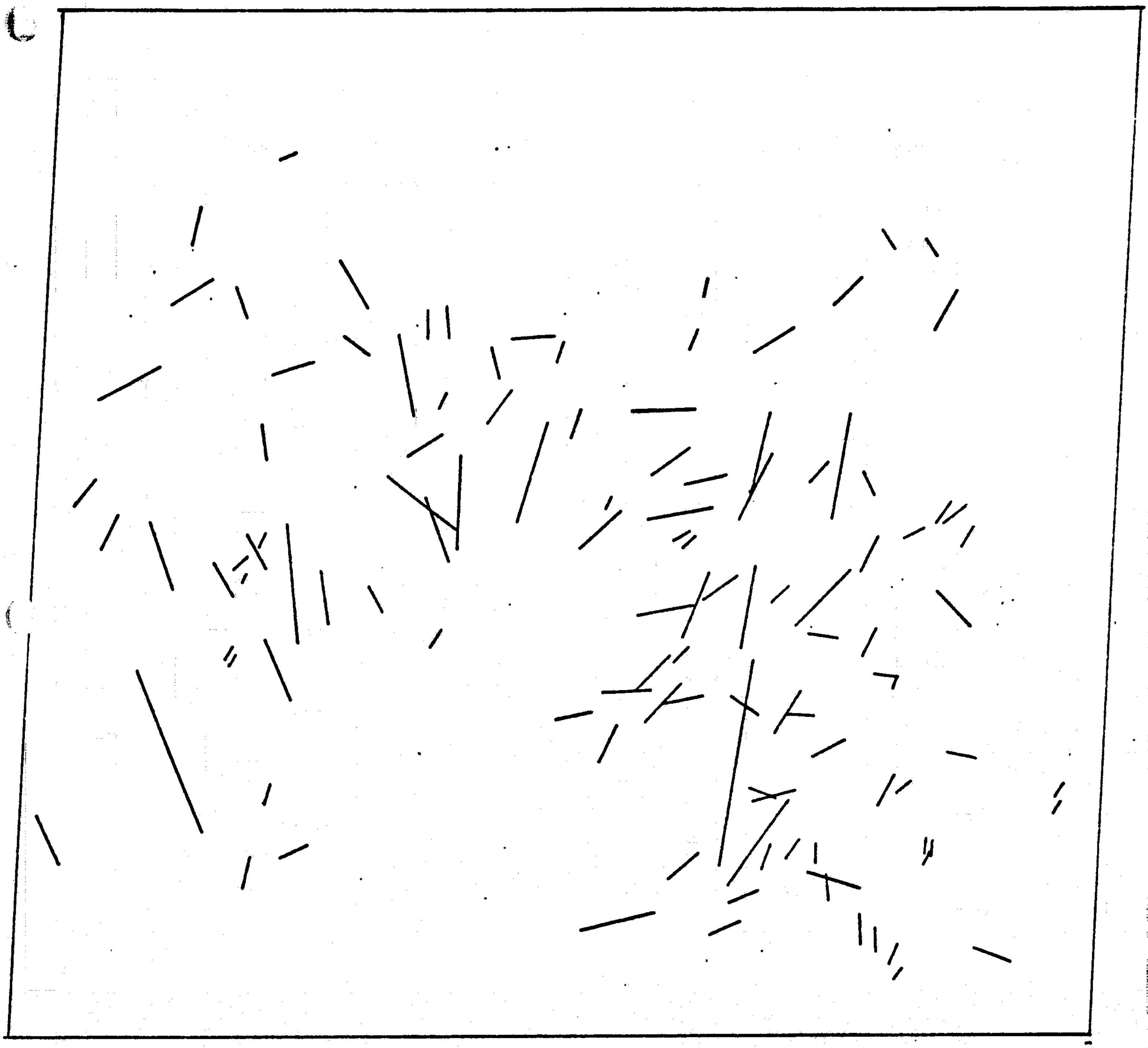


FIGURE 8b. LINEAR ANALYSIS OF SCENE E1228-15424 8 MAR 73
SHOWING DIFFRACTION GRATING METHOD RESULTS

307

FIGURE 8c. LINEAR ANALYSIS OF SCENE E1228-15424 8 MAR 73
SHOWING DIFFRACTION GRATING AND UNAIDED EYE
METHOD RESULTS

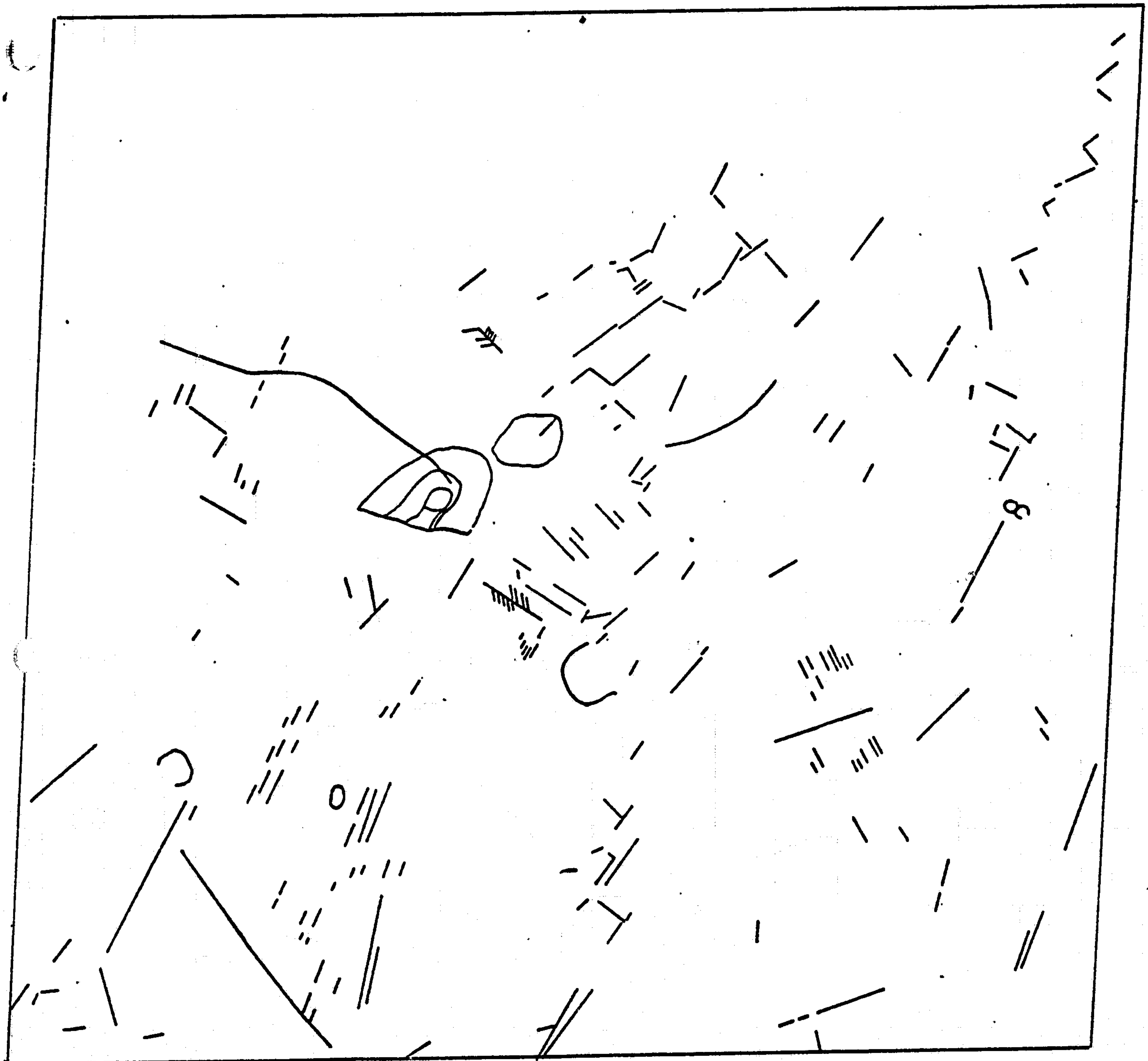


FIGURE 9a. LINEAR ANALYSIS OF SCENE E1605-15312 20 MAR 74
SHOWING UNAIDED EYE METHOD RESULTS

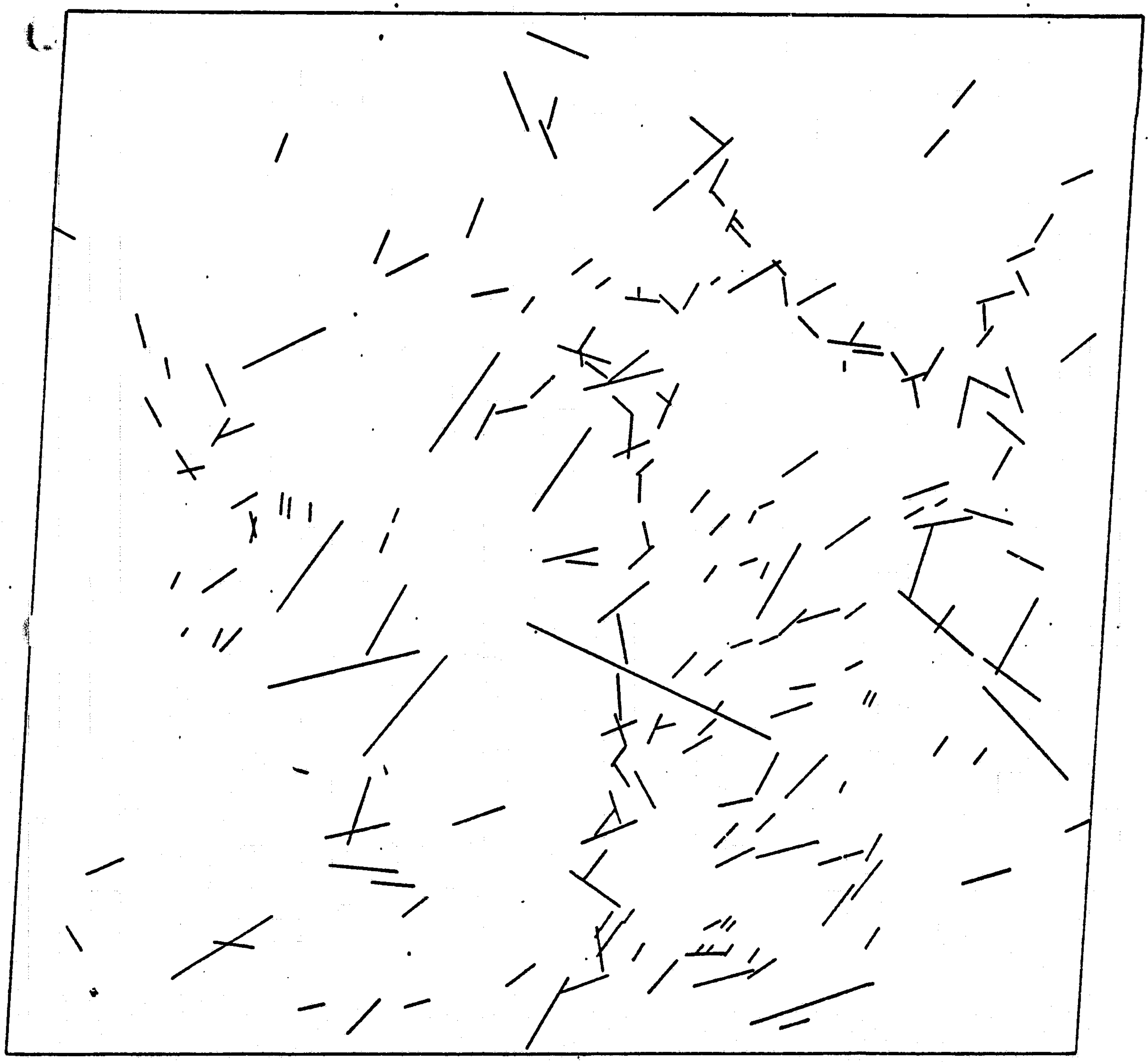


FIGURE 9b. LINEAR ANALYSIS OF SCENE E1605-15312 20 MAR 74
SHOWING DIFFRACTION GRATING METHOD RESULTS

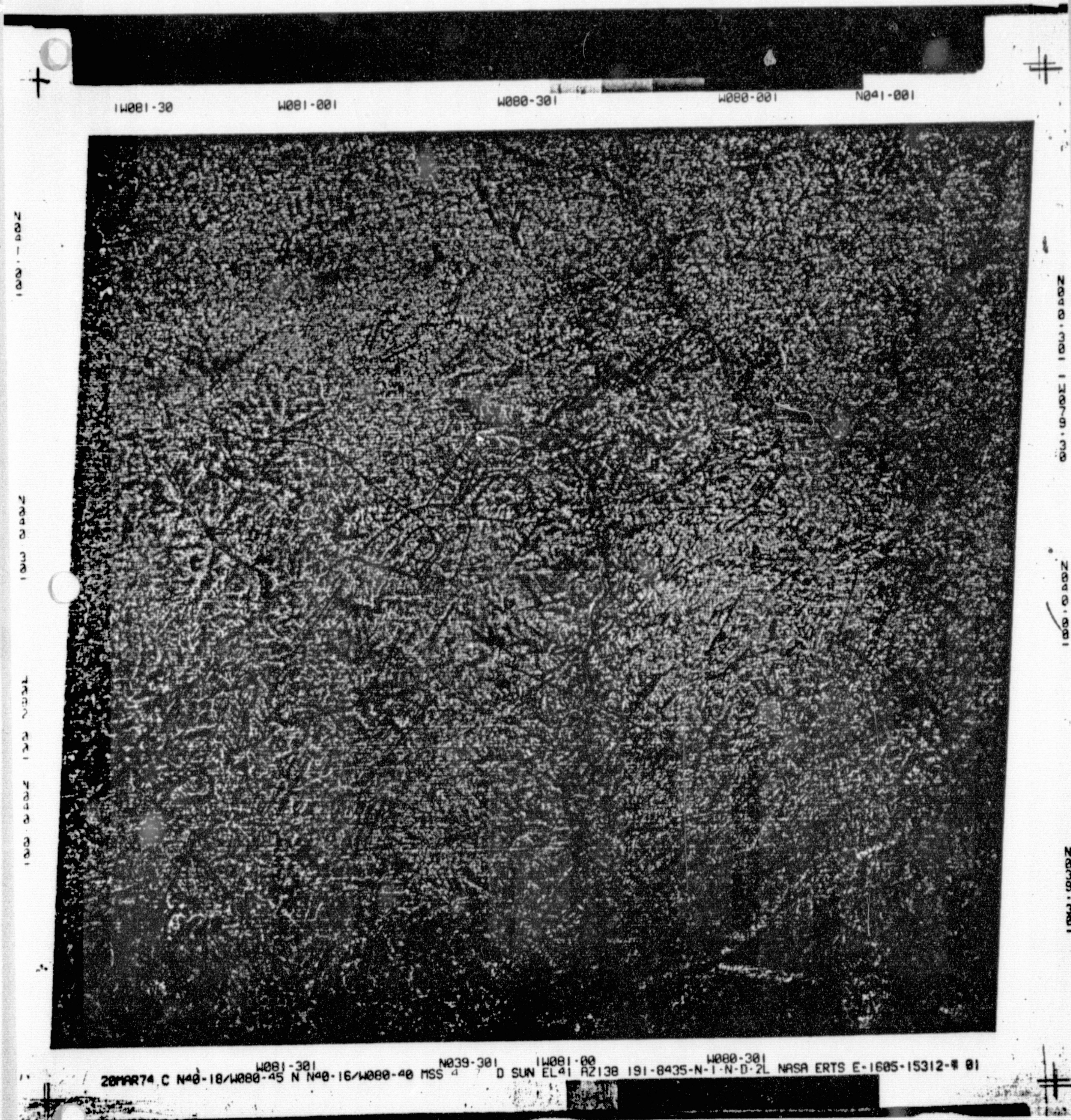


FIGURE 9c. LINEAR ANALYSIS OF SCENE E1605-15312 20 MAR 74
SHOWING DIFFRACTION GRATING AND UNAIDED EYE
METHOD RESULTS

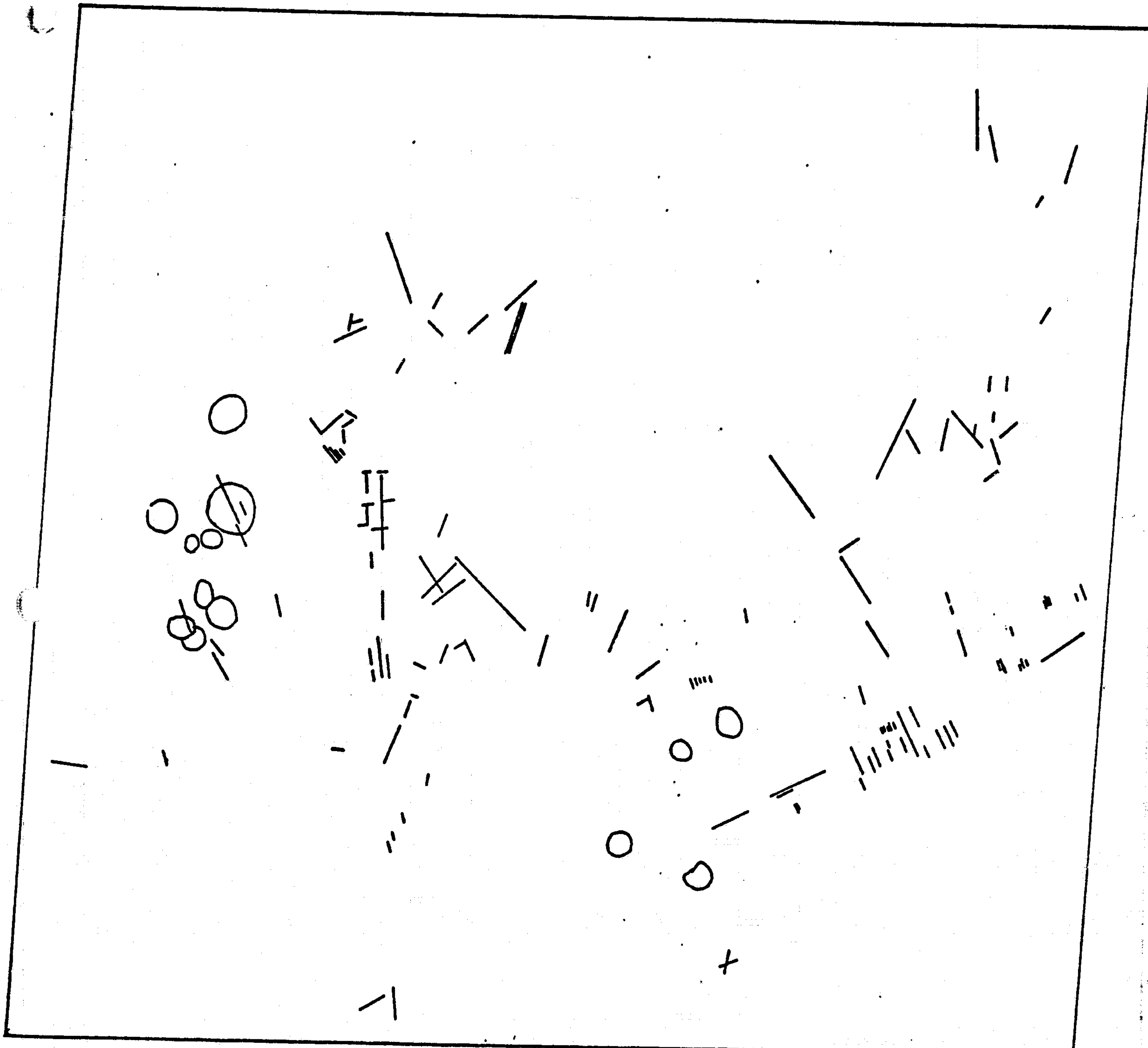


FIGURE 10a. LINEAR ANALYSIS OF SCENE E1228-15431 8 MAR 73
SHOWING UNAIDED EYE METHOD RESULTS

312

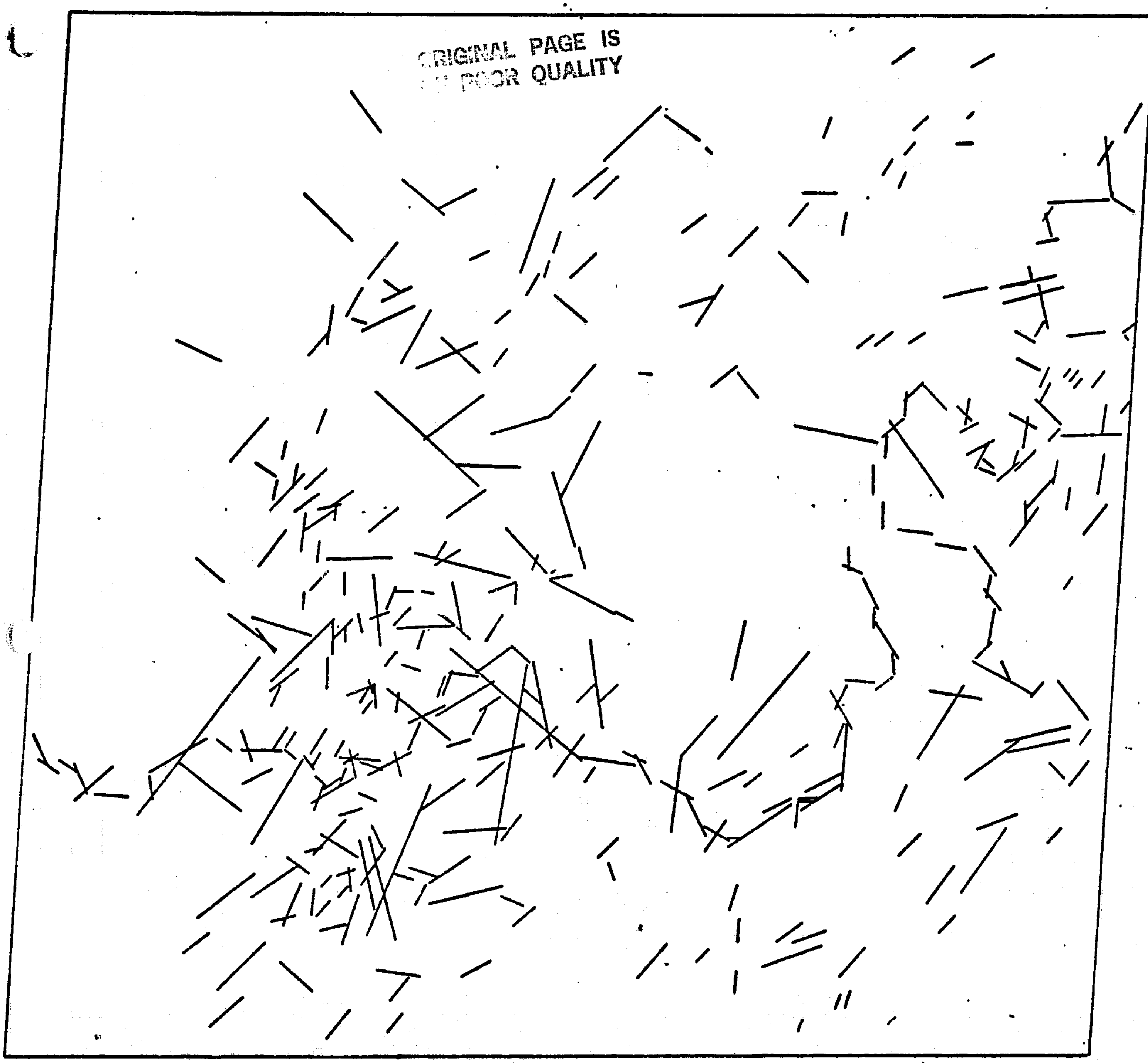


FIGURE 10b. LINEAR ANALYSIS OF SCENE E1228-15431 8 MAR 73
SHOWING DIFFRACTION GRATING METHOD RESULTS

ORIGINAL PAGE IS
OF POOR QUALITY

FIGURE 10c. LINEAR ANALYSIS OF SCENE E1228-15431 8 MAR 73
SHOWING DIFFRACTION GRATING AND UNAIDED EYE
METHOD RESULTS

314

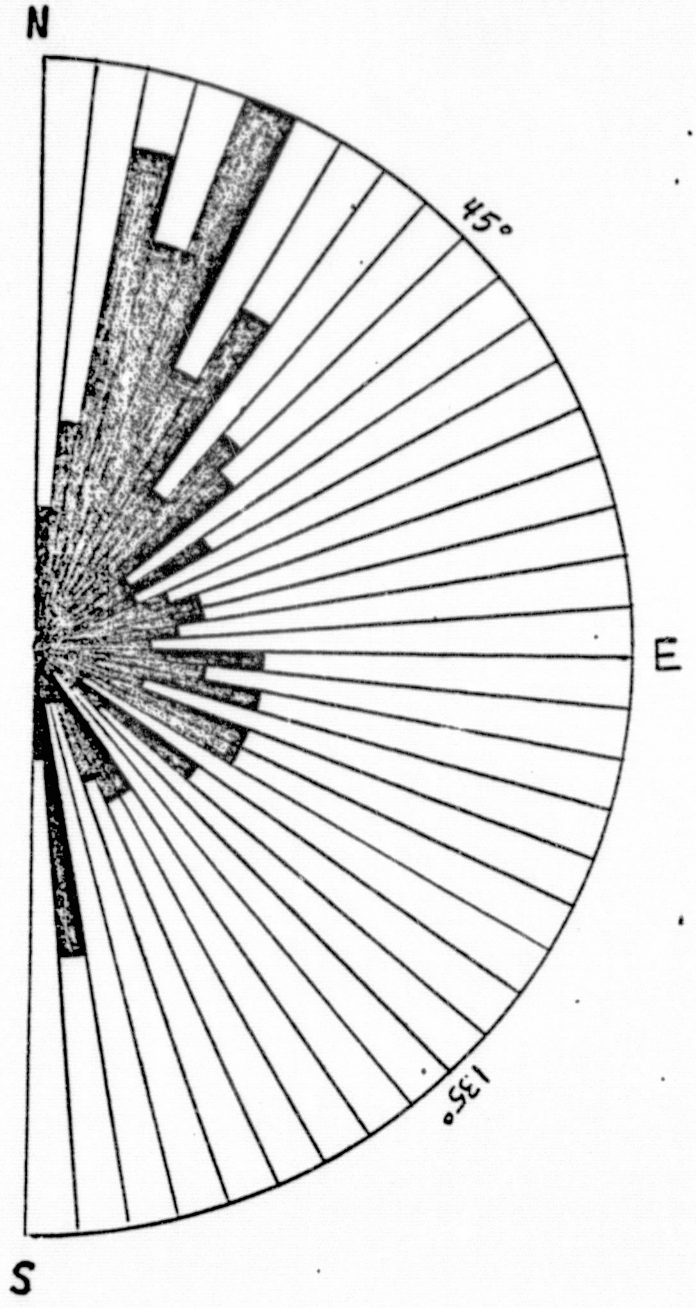


FIGURE 11a. NORMALIZED NUMBER OF LINEARS PER 5-DEG AZIMUTHAL INCREMENT VS. AZIMUTH

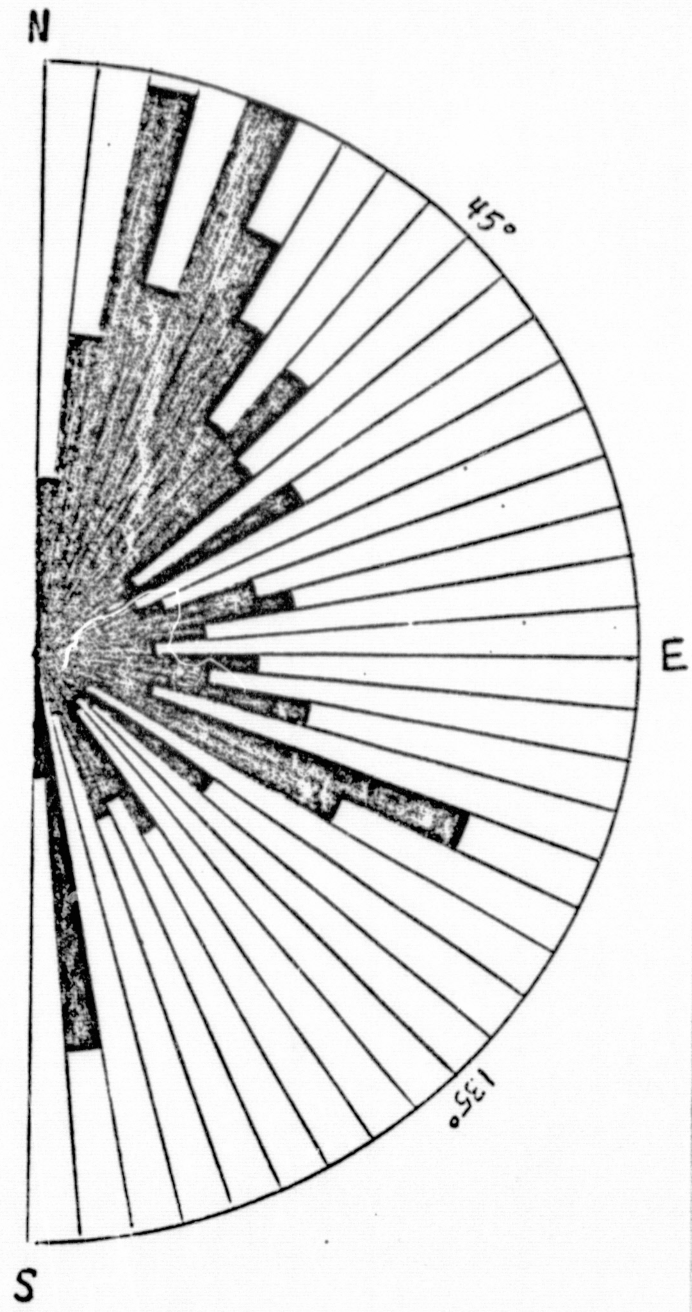


FIGURE 11b. NORMALIZED SUMMED LENGTH OF LINEARS PER 5-DEG AZIMUTHAL INCREMENT VS. AZIMUTH

315

This is a pattern of linear directions which has been expressed by geologists as being the expected and observed trend in glaciated areas believed due in part to the differential rebounds of rock strata from episodes of geologically recent continental glaciation. The results of glaciation were superimposed upon the regional lateral compression shear fractures and later tension fractures caused by cycles of the Appalachian Mountain building which thrust west through the central axis of the Appalachian Basin through the Eastern Coastal States. These joints and fractures would probably now be occupied by streams, being a guide for mass wasting and sedimentary "runoff" and would be expressed on the surface as valleys with opposing ridges, or other geomorphologic features. Using the unaided eye method, numerous circular features were plotted in the south central image along the western edge of the glacial boundary. One of these circular features is located near Serpent Mound in Pike County. Much discussion as to the origin of this feature has taken place. A current theory holds that the feature is due to a basement intrusion (laccolith, magma and/or gases) which extruded from a joint or fault complex into the base of the sedimentary section, coming in contact with the basal sediments. Other similar features have been identified on the surrounding area and may possibly be genetically related to the aforementioned feature. Curvilinear features were also identified in the east central image north of Cadiz. One feature measures 15 km across and the other 10 km. These features have a direct relationship with the stream patterns within their boundaries. Gas and oil fields are located on the edges of these features.

A cursory examination of the black and white LANDSAT images in all four bands of the south central scene seems to indicate that Band 7 (0.8 to 1.1 μm) is the best black and white band for the identification of linear features. It was found, by using two diffraction gratings in combination, that the imagery is further degraded in resolution but linears appear to stand out or to be further enhanced to the eye. This may make the plotting of linears an easier manual task. However, it is possible that the linears are also being elongated by the use of two gratings.

Preliminary evaluation of utilizing the Data Color Viewer for enhancement of linear features on LANDSAT imagery was attempted. This equipment has the capability of optically combining up to four 70-mm images and

enlarging them on a built-in rear viewing screen to the scale of 1:1,000,000. For this evaluation two LANDSAT images, Band 5 and Band 6 E1228 15431 8 March 1973, of South Central Ohio were chosen. A Band 5 positive image and a Band 6 negative image were placed in the viewer and registered. The image intensity of Band 5 was adjusted until the intensities of both images were equal. This provided a very "flat" image with very little detail. Band 5 was then offset or brought out of registration a very small amount. This technique provided an edge enhancement of features ("cameo effect") due to density differences on negative and positive. A large number of linear features and a large amount of very subtle detail were visible using this technique. However, due to time limitations of the project no linear mapping was accomplished utilizing this method.

The diffraction grating method proved to be a far superior method for the delineation of photolinears. However, one anomalous effect of the grating still proves to be suspect. When viewing the imagery through the grating, striations appear across the entire surface of the image area at right angles to the grating lines. These striations appear as an oriented smearing of all features in the image. At some positions these striations appear to be more intense than at other positions. After having a number of people, unrelated to the project, view the imagery through the grating, a trend of the direction of these intense striations was established to be NE-SW and NW-SE. After having established this striation intensity direction, the image was rotated 45 deg from the original position. The striations still appeared to be most intense at the same angle relative to the observer, as before. A random dot pattern was then used in place of the image and the results were similar, that is, an apparent, higher intensity of lineations resulted at a 45-deg angle relative to the observers no matter in which position the pattern was placed. This led to the hypothesis that there is a possible perceptual preference causing the anomaly. Insufficient consideration has been given to the problem, so that no conclusion can be made at present. However, the fact that there may be a predetermined visual preference indicates that these directions may be more

favored, by being easier to perceive, thus biasing the identification of linears in favor of these directions. This would have a tendency to place a favored 45-deg direction of linears in the NE-SW and the NW-SE direction, which is the geologically "expected" direction for joints and fractures in this area.

Conclusions and Recommendations

This task clearly demonstrated the feasibility of mapping geologic linear and curvilinear features in the State of Ohio utilizing LANDSAT imagery. For the first time, linear analysis and mapping in over two-thirds of Ohio has been done and placed in the public domain. Analysis has also been done for surrounding areas including a portion of the Appalachian Region.

This experiment has shown that conventional LANDSAT imagery is more responsive to regional-sized analysis than aircraft imagery and mapping of regional-sized areas can be easily and quickly done using LANDSAT imagery. The lower resolution of current LANDSAT imagery (≈ 80 meters) is well suited for large area analysis, and in fact actually obscures roads and other cultural features often misinterpreted as linears. However, for very localized (large scale) linear analysis, increased resolution of LANDSAT imagery or the use of high-altitude aircraft data is required.

LANDSAT imagery analysis using the unaided eye for interpretation is excellent for identifying subtle linear features, patterns, and anomalies. LANDSAT analysis using the diffraction grating method is excellent for isolating linear patterns directionally while reducing image resolution in all other directions, thus making analysis more rapid and complete.

The utilization of a positive/negative image overlap method (cameo effect) seems to be a promising optical method for linear mapping--a method which should be more throughly investigated.

Much analysis has been and is currently being done on the identification of photolinears from remote sensing data. However, little consistent work has been done to field verify photolinears and correlate them with presently known joint-fracture patterns and photolinear analysis. Numerous correlations have been found between photolinears and surface

expressed faults in most areas investigated, leading to the reasonable conclusion that there also may exist a correlation between photolinears and joints/fractures which can also be considered to be "faults" without displacement.

Based on the results of this experimental effort the following recommendations are offered:

(1) At least all major linears should be field checked for geologic significance. Certain of these should be investigated by geophysical techniques.

(2) More geophysical and geological studies of large curvilinear features and circular anomalies should be done to identify the cause and to investigate possible mineralization important to industry in these areas since these areas may be due to local "basement" tectonic activity.

(3) Investigations should be made into the possible perceptual problem and subjectivity of the eye-diffraction grating method. Research should be done to develop objective variations of the present methodologies or to develop entirely new optical or electronic methods of detecting photolinears which will be more objective and allow more rapid and more precise linear recognition and documentation. An automated optical and/or electronic system would fill these needs. These methods should be field tested and verified before a high operational demand is placed upon them.

(4) Standardization of methods and means of recording results must be made in order to make the identification and photolinear mapping as useful as possible.

(5) The construction of a pilot atlas or atlases of all LANDSAT imagery produced sequentially over the same ground target should be made to isolate effects of

season, sun angle, and other climatological variables. This will enable the best band or bands to be identified for linear and other analyses and new sensors or hardware to be recommended for future space platforms.

(6) The construction of a pilot atlas or atlases to combine the results of LANDSAT with other high- and medium-altitude photography and programmed SLAR should be pursued.

(7) The construction of a pilot atlas or atlases providing ground resource inventories is recommended.

This study has shown that LANDSAT data can be effectively utilized for mapping photolinears in Ohio and surrounding Appalachian areas. Such LANDSAT-derived linear maps have potential for (1) increasing the discovery of oil, gas, and minerals in the East mainly by providing a useful data input to reconnaissance exploration activities (particularly by smaller exploration companies of the type mostly operating in Ohio and the Appalachian area), and (2) increasing gas production significantly in eastern shale areas, if mapped linears are found to reveal the location and geometry of fracture/fault systems permitting the application of fracture stimulation techniques.

Use/User Implications

Contact was made with personnel of The Ohio State Geological Survey. Personal views from these discussions indicate that a linear survey of this type is much needed and will be important technically and economically for the oil and gas owner/operators. However, it was expressed that more analysis and field work need to be accomplished before linear mapping can be utilized operationally.

Discussions with an oil and gas well manager (William E. Shafer of Shafer Exploration Co.) proved to be very positive in an outlook to the future of linear mapping and its importance to the small oil and gas well operator in Ohio.

For a full discussion of his views and critique of this task, see the report entitled "Review of Lineation Observations by Battelle Columbus Laboratories LANDSAT Imagery, Ohio Southeast Quadrant", which follows this task report.

Bibliography

Overbey, W. K., Jeran, P. W., and Keck, D. A., "Relationships of Earth Fracture Systems to Productivity of a Gas Storage Reservoir", Morgantown Energy Research Center, West Virginia; U.S. Department of the Interior, Bureau of Mines Report of Investigations (1974).

Elder, C. H., Jeran, P. W., and Keck, D. A., "Geologic Structure Analysis Using Radar Imagery of the Coal Mining Area of Buchanan County, Virginia", Pittsburgh Mining and Safety Research Center, Pennsylvania; U.S. Department of the Interior, Bureau of Mines Report of Investigations (1974).

Pohn, H. A., "Remote Sensor Application Studies Progress Report, July 1, 1968, to June 30, 1969: Analysis of Images and Photographs by a Ronchi Grating", U.S. Department of the Interior, Geological Survey, Washington, D. C. (1970).

Halbouty, M. T., "Application of LANDSAT Imagery to Petroleum and Mineral Exploration", The American Association of Petroleum Geologists Bulletin, Volume 60/5 (May 1976), pp 745-793.

shafer exploration company
P.O. BOX 29068 - NORTHLAND STATION
COLUMBUS, OHIO 43229 U.S.A.

Tele: (614) 888-5080
Telex: 246-633
Cable: SHAFEREXCO
W. E. SHAFER
Professional Geologist

REVIEW OF LINEATION OBSERVATIONS BY BATTELLE COLUMBUS LABORATORIES LANDSAT IMAGERY, OHIO SOUTHEAST QUADRANT

BY

WILLIAM E. SHAFER
CONSULTING GEOPHYSICIST
COLUMBUS, OHIO

October 22, 1976

1333 FIRWOOD DRIVE, COLUMBUS, OHIO 43229 U.S.A.

322

A certain cursory review was made of subject "linears, "curvilinears" and "circulars" observed by Battelle Columbus Labs, upon LANDSAT imagery and transposed to contour maps of the U. S. Army Map Service (R.M.P.V.) Corps of Engineers, Scale 1:250,000.

The requested manuscript review was directed to the writer as an independent practitioner in the Ohio-Appalachain oil and gas industry.

CHARACTERIZATION OF THE OHIO APPALACHAIN OIL AND GAS OPERATOR

An independent person or a small group of people, often times incorporated, essentially dependent upon external financing from the private sector, usually understaffed and operating on a very restricted operations budget.

CHARACTERIZATION OF PRODUCT

Settled oil production from and above the shallower Silurian reservoir is usually classified as "stripper well" production, (10 bbls. per day or less) being 70% of all Ohio oil production. Fifty percent is classified "Pennsylvania Grade", 31% is "Corning Grade" and the remaining 19% is comprised of special classified grades. The crude oil is usually "sweet"or essentially sulphur free. Petroleum value is 12.1% of the total mineral value in Ohio.

Gas production is usually relatively low volume, with modest, average deliverable reserves, less than 150 to more than 400 MMCF gas per well. The gas is usually "sweet" with a Btu range of 1020 to 1070.

CERTAIN PRODUCTION HISTORY

Approximately 122,577 wells have been drilled in Ohio from 1884 to 1976. A ten year average is 1,609 wells per year. During 1975, a comparatively lower activity year, a total of 1,248 wells were drilled in Ohio. The Silurian, Clinton-Medina sandstone reservoirs accounted for 90% of these wells being drilled to an average depth of 4,240 feet below ground level. Ninety-three percent of the holes drilled to the Clinton-Medina sandstone produce commercial hydrocarbons. The Mississippian, Berea sandstone reservoirs accounted for approximately 5% of the wells with 87% being productive of commercial hydrocarbons. The average depth of the Berea wells was 1,320 feet below ground level.

Other shallower and deeper reservoirs comprise the remaining 5% of the commercially productive wells and includes the Ohio Devonian shale which accounted for .5% of the wells with 83% being productive of gas at an average depth of 2,027 feet below ground level.[1] All wells drilled to the Clinton pass through the Ohio Devonian shale.

The dollar value of crude oil produced in Ohio during 1975 was $113,916,537.00. The average price per barrel at the wellhead was $11.89. The dollar value of natural gas produced in Ohio during 1975 was $60,604,235.00. The average price paid at the

[1] Ohio Division of Oil and Gas, Annual Report, 1975

wellhead was 70.6¢ per MCF (thousand cubic feet). An estimated 850 MMCF (million cubic feet) was not sent to market but was utilized as fuel on lease property, landowner's residence or consumed in flares.[2]

During 1974, 92,558 MMCF natural gas was produced in Ohio and 1,086,651 MMCF natural gas was consumed within the State. This is a deficit of 91.5% of the State's natural gas requirements. This deficit was essentially met by interstate gas supplies from the Gulf Costal States.

During the same year, 1974, 8,964,000 barrels of crude oil were produced in Ohio and 212,783,000 barrels of refined liquid product was consumed within the State. This deficit, 96% of the State's requirement, was essentially met through interstate and foreign distribution, (61% by the Gulf Coast and Western States, 13% by Western Hemisphere Countries, and 23% by Eastern Hemisphere Countries).

During 1975, the foreign Western Hemisphere imports to the U.S.A. decreased by 45% and the Eastern Hemisphere imports increased by 55% of 1974 imports.

[2] Independent Petroleum Association of America, 1976.

CHARACTERIZATION OF LANDSAT LINEATIONS

TYPE	FIRST "RATIONALE" CONCLUSION
1. "Circular" Anomaly	Represents a visual specific drill target potential.
2. "Curvilinear" Anomaly	Represents a visual, partial drill target potential.
3. "Straight line" and "Line clusters"	Represents potential productive trends.

"Circulars" were noted on the Analysis Scene E-1609-15312, E-1228-15424 and E-1228-15431 LANDSAT images. Below tabulated are example LANDSAT "Circular" areas and their direct relationship to the presence or absence of associated oil and gas facts: (The "Circular" area name was chosen to identify the geographic location)

"CIRCULAR" AREA	OIL AND GAS FACTS			
	Field Name	Year	Reservoir	Depth
Tuscarawas County (New Philadelphia)	Urichsville	1937 1970	Berea Clinton	1,000' 5,025'
	Mt. Bethel	1902 1940	Berea Clinton	1,000' 5,265'
	Yorktown	1923 1966	Berea Clinton	700' 4,865'
	Roswell	1943 1943	Berea Clinton	900' 5,135'
Harrison-Carrol Counties (Jewett)	Scott Run	1900	Berea	1,300'
	Scio	1899	Berea	1,350'
	Dining Fork	1899	Berea	1,350'

	Elk Lick	1922	Berea	1,350'
	Loudon	1914	Berea	1,350'
	North Loudon	1937	Injun	725'
	Kilgore	1910	Berea	1,300'
Jefferson County (Shane)	Wolf Run	1922	Berea	1,400'
Belmont County (Martins Ferry)	Barton	?	?	?
	Burlington	?	Injun	1,300'
	Patton Run	?	Injun	1,100'
	Colerain	1894	Berea	1,900'
Guernsey County (Cambridge)	Byesville	1885 1969	Berea Clinton	1,100' 4,975'
	Cambridge	1929 1924	Berea Oriskany	1,400' 3,400'
Lawrence County (Linnville)	Willowood	1930 1966	Devonian Shale Clinton	2,500' 3,585'
(N.E. Ironton) "Ice Creek"	Ironton	1913	Devonian Shale	1,800'
	Hecla	1928	Devonian Shale	1,900'
Adams County (Dunklesville) "Cluster"	None	____	____	____
(Serpent Mound)	None	____	____	____
(Carmel)	None	____	____	____
Highland, Pike, Ross Counties	None	____	____	____

KENTUCKY

Greenup County (Ashland)			Salt	1,100'
			Berea	2,000'
			Devonian Shale	3,300' to 3,600'
Boyd County (Savage Branch)	Ashland	1918	Devonian Brown Shale	1,760' to 2,200'

"CURVILINEAR" AREA (Examples - Scene E-1605-15312)

Coschocton & Muskingum Counties (Nickel Valley)	Pike-Coshocton	1912	Clinton	2,850'
	Perrytown	1912	Clinton	2,825'
Belmont & Monroe Counties * (Allendonia)	Allendonia	1920	Berea	2,000'
	Pency Fork	1913 1916	Berea Keener	2,200' 1,650'

"LINEAR" AREA (Examples - Scene E-1228-15431)

Scioto County (East) Scioto Valley Complex (Minford)	Minford	1930 1930	Berea Ohio Shale	400' 1,500'
	Long Run	1930 1930	Berea Ohio Shale	400' 1,500'
	Lucasville	1926	Berea	150'
	Schuller Hollow	1926	Berea	350'
	New Boston	1922	Berea	400'
Pike County (East) (Geneva-Beaver)	Beaver	1929	Ohio Shale	500'

* Other fields also present.

The preceeding high density lineation scene extends into Greenup County, Kentucky. No oil and gas fields have been discovered at this time in the Kentucky portion of this lineation scene. The Ohio portion of the "Scioto Valley Complex" is void of oil and gas production records except as previously noted. Drill operations interest in the traditional shallow reservoirs appear to be lost by either erosion, proximity to ground surface, or adverse variations in (reservoir) lithology. The deeper reservoir potentials have not been adequately tested in this area and most other areas of the State.

Approximately 80% or more of the linear representations (Scenes E-1228-15431, E-1228-15424 and E-1605-15312) on the east side of a line from Lorain to Lancaster to Portsmouth, Ohio are involved in NNE-SSW post-Ordovician oil and/or gas field producing areas. The deep potential reservoirs remain essentially untested by the drill in this area.

Lineations extending into West Virginia (Scene E-1228-15431 and E-1605-15312) in a zone from Charleston to Parkersburg include ten separate NNE-SSW oil and gas field areas which are essentially extensions of the Ohio and Pennsylvania style post-Ordovician reservoirs.

Lineations extending into Pennsylvania (Scene E-1605-153120) in a zone area centered about Pittsburgh include many separate NE-SW trending oil and gas field areas which are discrete sandstone reservoirs

contained in the Devonian and Mississippian shales. Certain of these sand reservoirs extend into Ohio with decreased frequencies of occurance. Also, certain of these reservoirs extend into West Virginia.

EXAMPLES OF LINEAR RELATIONSHIPS TO PARTICULAR AREAS OF OIL AND GAS INTEREST

AREA	LINEARS
Holmes County - N.E. Area (Mt. Hope)	No image data
Guernsey County Area (Old Washington)	3 NE linears
(Ava - Cumberland)	no image data
Noble County Area (Hoskinsville)	NE & NW proximal linears
Morrow County Area (Mt. Gilead-Cardington)	NE linears (scattered)
Delaware County Area (Center Village)	NW & NE proximal linears

EXAMPLES OF LINEAR RELATIONSHIPS TO PARTICULAR COLUMBIA GAS CORP. GAS STORAGE AREAS

Guernsey County, NW ((Postboy)	1 NE linear (short)
Hocking County, West (Hocking State Forest)	1 NE linear (long)
Vinton County, West (Wayne National Forest)	NE linears (few)

OBSERVATION OF POSSIBLE INTERFERING MAN-MADE LINEATION

Electric Transmission Easements	no correlation

Pipeline Transmission Easements	no correlation
Interstate Highways and Easements	no correlation

PRIORITIES BY VISUAL IMPACT OF LANDSAT SCENES PER MAPPED LINEATIONS

1. Scene E-1605-15312 Canton Area
2. Scene E-1228-15424 Newark Area
3. Scene E-1228-15431 Portsmouth Area

Previous self-styled linear classification statement dictates that greater view attention is given apparent circular anomalies as potential drill targets. However, tempered by the knowledge that given two separated circular anomalies, this writer is attracted to that area of best oil and gas production histories. This statement shall be expanded in the discussion statement.

CURSORY "DISTANT" VIEW OF APPARENT DOMINANT LINEATION TREND DIRECTIONS (IMPRESSION) BY QUADRANT ONLY

1. Scene E-1605-15312 NE & NW (equal)
2. Scene E-1228-15424 NW (W/2) and NE (E/2)
3. Scene E-1228-15431 NW

The Battelle pilot program computer measured lineation azimuth, Scene E-1228-15431, indicates the dominant lineation to be in the NE Quadrant and the dominant length to be in the NE Quadrant. This scene had a particularly high population of apparent major and minor lineation sets falling into the two adjacent Quadrants. The computer organization of data is apparently particularly helpful to proper, rapid lineation analysis.

EXAMPLES OF APPARENT EFFECTS OF BURIED OR PARTIALLY BURIED TOP BEDROCK ERROSIONAL SURFACE CORRELATION WITH LINEARS

AREA	APPARENT CAUSE
Columbus, North	NNW trending buried valleys
Mt. Vernon	NW & NE trending buried valleys
Chillicothe	NW & NE trending buried valleys
Derby	NW trending buried valley(s)
Waverly	Topographic expression of (Teays) valley wall in part and aligned tributary projecting into NW trending buried valley system.

EXAMPLES OF DRAINAGE BASIN CORRELATIONS

The Scioto Basin is elongate North-South. A possible subtle linear system change in population and azimuth from NNE to NNW occurs at the east margin of the drainage basin.

The Muskingum River Basin is elongate NNE-SSW. The NE part of the concentric "New Philadelphia" circular is involved in the drainage divide but does extend into the adjacent Ohio River Drainage Basin. The Cadiz linear in this same area is on the drainage divide. The geologic surface map indicates an arcuate outcrop pattern of Monongohela errosional remnants in the area.

In the Ohio River Drainage Basin at Wheeling, West Virginia, there are closely spaced lineations on stream divides, normal to the Basin boundary with subset lineations in approximate 45° tributary

relationship. This regular pattern should be investigated for correlation with coal cleat sets in the involved Pennsylvania and Permian rock formations. In this respect, investigators must be aware of surface effects of coalbed pseudo structures and possible Silurian salt section anomalies.

The major (Teays) preglacial drainage pattern was extensive in Central Ohio and drained to the NW with a NW trending basin which now includes several existing north, NE and NW trending basins.

LINEAR CORRELATION WITH SUBTLE SURFACE STRUCTURAL FEATURES

No particular lineation correlation is evident between the NW trending so-called "Parkersburg-Lorain Syncline" and "Cambridge Arch". A possible lineation correlation is evident in the area of the NE trending "Huntington Syncline".

EXAMPLE OF LINEAR CORRELATION TO GEOPHYSICAL EVIDENCE

The Gravity Map of the United States (U.S.G.S. 1964) represents at least two gross systems merging within Ohio. A positive arcuate NW gravity trend (two sets) is evident extending through Western Ohio. Central Ohio appears to be a mixture of positive and negative anomalies trending NNE. A negative NE gravity trend is evident extending through Eastern Ohio. The LANDSAT lineations appear to be honoring both major NW and NE influences. It is obvious Ohio has been and is a focal point for gravity related dynamics.

Detail seismic reflection data from a five township area in Morrow

County, Ohio indicates numerous, essentially NNE and NNW trending sets of Cambrian structural terraces. This area (Morrow County Consolidated Oil Field) discovered in 1963, is a pre-Ordovician buried subcrop reservoir at the top of the Cambrian (old) erosional surface. In this writer's opinion, these structural terraces seem to be controlled by low displacement (down to the Basin), normal Basement faults and are apparently cut by low displacement WNW and ENE transverse (sheer) faults. The Top Cambrian errosional surface (Knox Unconformity) apparently developed upon these (faulted) zones-of-weakness. Post unconformity, differential compaction (sedimentary) and other geologic processes have been noted (well log examination) to attenuate upward from many positive Knox Unconformity anomallies and extend, in some cases, into the near surface, Devonian "Big Lime" formation. These causal rock stress relationships appear to be effect-related in the geomorphic record by gross, but subtle, LANDSAT and other land surface related observations.

DISCUSSION

The literature is nearly void of measured joint orientation field observations. The Devonian Shale, Report No. 27, Division of Geological Survey, Ohio, does list the following data:

AREA	JOINT FIELD ORIENTATIONS	
Columbus	Vertical	NE & NW
Bellefontaine	Vertical	N-40-W & N-55-E
Conneaut-Ashtabula	Vertical	N-55-W & N-40-E

This report states that joint orientation in the Devonian Shale shows greater variation in the NW azimuth. The report also states joints cut cleanly through rocks of different types and styles.

In this writer's opinion, the LANDSAT linear features are significant.

1. The various anomalies illustrated encourage exploratory investigation which may cause a commercial mineral discovery. In the case of the"circulars"in eastern Ohio, prior to oil and gas development, "shallow" oil and gas would have been discovered if the circular had been drilled first. In southwestern Ohio, to date, commercial oil and gas discovery has not yet occurred. The deep potential reservoirs in all of Ohio have not been adequately tested.
2. If lineations correlate with joint patterns, the probability of fracture enhanced reservoirs in the trend of the lineations is apparent. Productive trend projections are important to the oil

and gas discovery success ratio.

3. All linears represent a significant amount of new investigative evidence which, coupled with other exploration tools, shall inexpensively increase the discovery rate of oil, gas and other minerals.

4. The linears appear to be expressions of a multitude of dynamic influences upon the earth's crust. At this early time of view it is difficult to sort out the variety of influences and thereby geologically categorizing the cause-effect relationship. However the categorizations may not be as important as an observed relationship between oil and gas occurance and the family of linear or circular anomalies, as long as the linears or circulars survive certain tests of authenticity.

5. The linear features appear to be a response to geologically ancient and also recent geological circumstances. The effect of the compressive forces of the Appalachain Mountains building episodes and subsequent relaxation of same have been an important, if not perhaps an overriding influence. The plate tectonic hypothesis is, of course, an important part of the Appalachain tectonic story. The relaxation of Appalachain compressive forces and the basement differential zones of rock types and ages, possibly defining reactivated fault zones, have influenced the structural responses in Ohio. The "up-thrown" Serpent Mound fault complex appears to be on such a dynamic NW-SE basement trend. It is significant that

western Ohio-Indiana appears as a "stable" area throughout geologically recorded sedimentary time when crustal subsidence and basin-filling occurred upon nearly all of the borders of this "stable" zone area. The gravity trends are but poorly understood, but apparently indicate a part of the ancient geologic history of Ohio which the LANDSAT lineation appears to support.

6. When viewing the LANDSAT linears it is important to proceed within the context of the following rationale:

(a) The rock composition and the dynamic structural history of the Appalachain Basin caused zones of weakness in the rock units.

(b) These zones of weakness produced joints and faults in preferred directions in (apparently) nearly vertical planes.

(c) The subsequent drainage eroded into mature topographic features favoring one or more zones of (rock) weakness, ie. joint sets.

(d) Continental glaciation generally enhanced the main pre-existing topographic patterns except much of the drainage flow was, more or less, reversed and joint patterns continued to control the drainage. The post-glacial buried valleys were filled with particular aluvium, compacted (differentially) and can still, in many cases, be seen by various subtle image effects. The repeated alignments of systematic bedrock related events cause the lineation in glaciated and non-glaciated areas alike. The investigator should however, be aware of the masking effects of recessional moraines.

(e) Many topographic features are responsive to bedrock structural influences.

(f) Therefore, bedrock structures, particularly joint (and fault) evidence and evidence of deep section disturbance can indicate effective gas and fluid entraping mechanisms and also can indicate gas and fluid reservoirs. These enhanced conditions are worthy of a test by the drill. The various sophisicated, successful gas and fluid fracture techniques used since 1954 to stimulate new (and old) gas and oil wells take advantage (act upon) the planes-of-weakness and open joints in the reservoir rocks of interest. The success of these techniques is testimony to the availability of reservoir related joints. This writer notes all rock outcrop areas visited in Ohio have an observable joint system.

RECOMMENDATIONS

1. Selected LANDSAT, high and medium altitude photography "lineations, curvilinears and circulars" must be field checked for field identification of features in-fact, including numerous measurement of rock joint sets where ever possible.

2. One or more pilot atlas(es) of sequential LANDSAT imagery should be compiled to determine the optimum season(s), sun angle and sensor wave length band or bands in various Appalachain work areas.

3. LANDSAT linears should be mapped by optimum sensor(s) from the core of the Appalachain, NW into the Appalachain Basin to the western boundry of same basin to progress from known systems of surface joints and faults. This can be done in separated parallel, continuous scenes of appropriate width and "filled-in" during subsequent programs.

4. Down-hole determinations of joint strike and dip (orientation) before and after "frac" treatment should be encouraged, supported and requested from operators whenever possible.

5. All data should be acquired and processed to prove or disprove the chain of logic presented in the "discussion" segment of this report, Item 6, a thru f, upon which linears have been related to rock joints under a variety of geomorphic conditions. The credibility of the LANDSAT and air photo linear measurement technique must be always subject to as much proof as is reasonable to apply. In this respect, the basic support data is available literally, on the surface, and can be measured, in many cases, down the bore hole.

6. The proof that surface expressed linear concentrations also occur underground (in the subsurface) is essential to establish and can be established.

7. A further geologic rationale must be developed and demonstrated explaining fracture seal and fracture preservation throughout the sedimentary section, in reservoir areas and upon the surface of the ground.

8. First generation LANDSAT linear progress maps, properly labeled, should be systematically constructed and made available to the public as soon as possible.

9. Continue to sponsor correlative geological and geophysical LANDSAT-air photo studies of the Appalachain Basin.

Respectfully submitted,

William E. Shafer

William E. Shafer

WRITER'S COMMENTS

The approximately 350 to 400 independent Ohio oil and gas operators are called "Independent Producers", along with similar operators in the other states within the oil and gas industry.* The role that all of the approximately 10,000 Independent Producers play within the (domestic) national oil and gas industry is important. Historically, the Independent Producers drill 89.2% of the "wildcat" oil and gas test wells searching for new reserves. The Independent Producers have discovered 53.8% of all new oil and gas reserves and 75% of all new oil and gas fields.** The Independent Producers, are in fact, very competitive and aggressive with each other individually and they are likewise, very competitive and aggressive in the same exploration and development areas of interest with the largest national and multi-national (Major) oil and gas corporations.

The Independent Producer currently provides nearly 100% of the oil and gas exploration and development activity within the State of Ohio. In the other Appalachain States, a few of the Major oil and gas corporations are apparently only infrequently engaged in limited exploration activity. The Independent Producers provide continuous oil and gas activity within each of these states.

Year 1974 (last year of record) 15,406 "stripper wells" produced 6,362,000 barrels of oil in Ohio, being 1.147 barrels per day per well average. In same year of record, 366,095 "stripper wells" produced 411,936,000 barrels of oil in the United States (Lower 48),

being .3125 barrels per day per well average.*** Stripper well production is an important part of the National oil reserves supply.

The recommendation for one or more pilot atlas(es) (See Page 17, Item 2) should include same target area comparison of the various enhancing software, hardware and hard copy processing for optimum geological view of the target scene and (personal) perception, "loss or gain" of the subject linear, curvilinear and circular family sets, including other data (pixel) organizing techniques (study area pixel signatures).

William E. Shafer

William E. Shafer

November 4, 1976

* Ohio Oil and Gas Association, January, 1976

** Independent Petroleum Association of America, May, 1976

*** Independent Petroleum Association of America, 1976 "Stripper Well Survey"

TASK 2. LANDSAT LAKE ERIE SEDIMENTATION ANALYSIS

TASK 2. LANDSAT LAKE ERIE SEDIMENTATION ANALYSIS

Background

Sedimentation pollutes surface water bodies of all sizes and presents a number of environmental and economic problems. The cost of dredging on a regular basis to remove sediments from bays, harbors and waterways is very high. Sediment particles may also carry with them toxic materials which may be deposited in a localized area, creating a potential public health hazard. Shore erosion and erosion of agricultural lands are of both economic and environmental concern in Ohio. Estimates of sediment production in tons per year per square mile for areas bordering Lake Erie are shown in Figure 12. Over 400 tons a year per square mile are eroded from some areas in Western Ohio.

The ability to measure sediment load, to identify the source of the sediments and to model the potential effects in areas receiving the major portion of deposition would greatly enhance state agencies' capabilities to manage problem areas before serious environmental damage occurs.

Objective and Scope

The overall objective of the Lake Erie sedimentation task was to investigate the feasibility of utilizing remote sensing data, specifically LANDSAT imagery, for determining suspended sedimentation levels and seasonal distribution of sediment loads in Lake Erie.

The planned scope of this task was to investigate and analyze sedimentation discharge in Sandusky Bay, Ohio. However, this analysis was not feasible as a result of the complete lack of hydrologic data which was expected to exist for the area. The only data available were infrequent and occasionally collected data at a water quality station on a tributary of the Sandusky River 40 miles upstream from the river mouth on the bay. Because of the limited and partial sampling of the Sandusky River confluents in the tributary, these

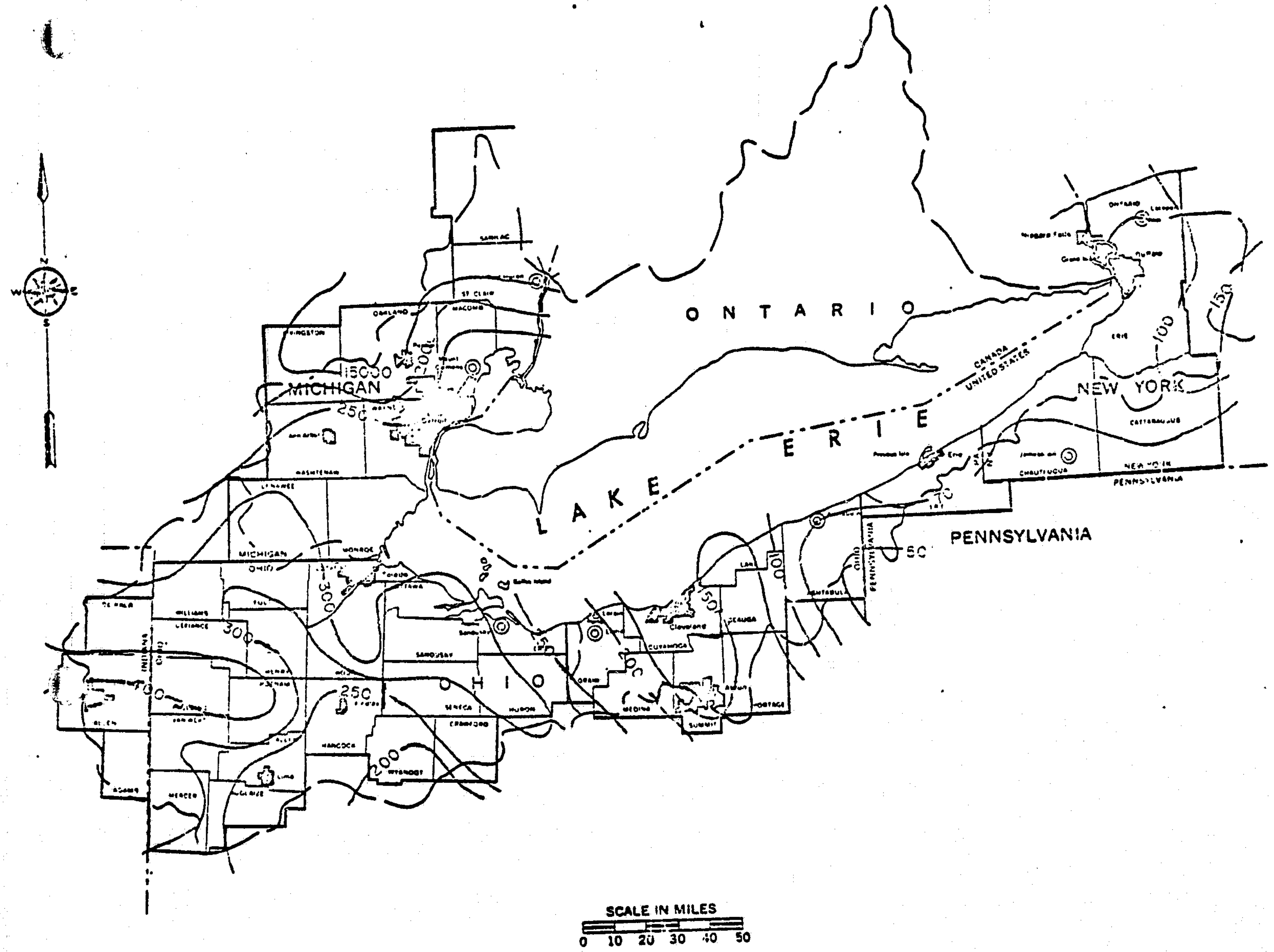


FIGURE 12. ESTIMATED SEDIMENT PRODUCTION IN TONS/YEAR/SQUARE MILE OF LANDS DRAINED BY TRIBUTARIES OF LAKE ERIE

Source: Great Lakes Basin Framework Study, Appendix 18: Erosion and Sedimentation, Great Lakes Basin Commission, 3475 Plymouth Road, Ann Arbor, Michigan 48106, 1975, page 110.

ORIGINAL PAGE IS OF POOR QUALITY

data were not considered appropriate for analysis. Therefore, the study area was expanded from the Sandusky Bay area to include the Western Basin of Lake Erie.

Sixteen LANDSAT 1 and LANDSAT 2 scenes covering the Western Basin of Lake Erie were analyzed. The dates and scene numbers are shown in Table 2. Efforts were made to obtain hydrologic information, including sediment load data, for the study site on the dates of the LANDSAT overpasses, but such data were unavailable. However, water and sedimentation discharge data were available from the U.S. Geological Survey's Water Quality Monitoring Station located on the Maumee River at Waterville, Ohio. This site is located approximately 21 miles (33.9 km) upstream from the point where the mouth of the river enters the Toledo Harbor. These data were acquired for the LANDSAT overpass dates.

Methodology

A Macbeth Transmission Densitometer (Model TD-102) was used to obtain film transmissivity measurements for four points on each LANDSAT frame. These points are as follows:

(1) The quarry on Marblehead Peninsula

(2) The mouth of the Maumee River where it outfalls into the Toledo Harbor

(3) The approximate center of the Western Basin of Lake Erie

(4) The highest density step of the density wedge at the bottom of each LANDSAT frame.

These sample points are shown on the map in Figure 13. Measurements directly at the image point (Maumee River) where the sedimentation data were obtained were not feasible due to the small scale of the imagery and the large spot size of the densitometer. Transmissivity measurements were made on LANDSAT Bands 5, 6, and 7. The sedimentation discharge data measured were in tons/day plotted on the y-axis of semilogarithmic graph paper with the imagery dates providing the scale for the x-axis. The film transmissivity measurements for each scene date were plotted on the y-axis using the same x-axis time scale.

TABLE 2. LANDSAT 1 AND 2 SCENES USED FOR THE SEDIMENTATION ANALYSIS ON LAKE ERIE

Scene Number	Image Date
LANDSAT 1	
E1247-15481	27 Mar 73
E1265-15480	14 Apr 73
E1319-15474	7 Jun 73
E1337-15472	25 Jun 73
E1391-15464	18 Aug 73
E1445-15453	11 Oct 73
E1427-15460	23 Sept 73
LANDSAT 2	
E2117-15353	19 May 75
E2135-15355	6 June 75
E2189-15352	30 July 75
E2261-15342	10 Oct 75
E2297-15340	15 Nov 75
E2315-15335	3 Dec 75
E2441-15311	7 Apr 76
E2513-15292	18 June 76
E2531-15285	6 July 76

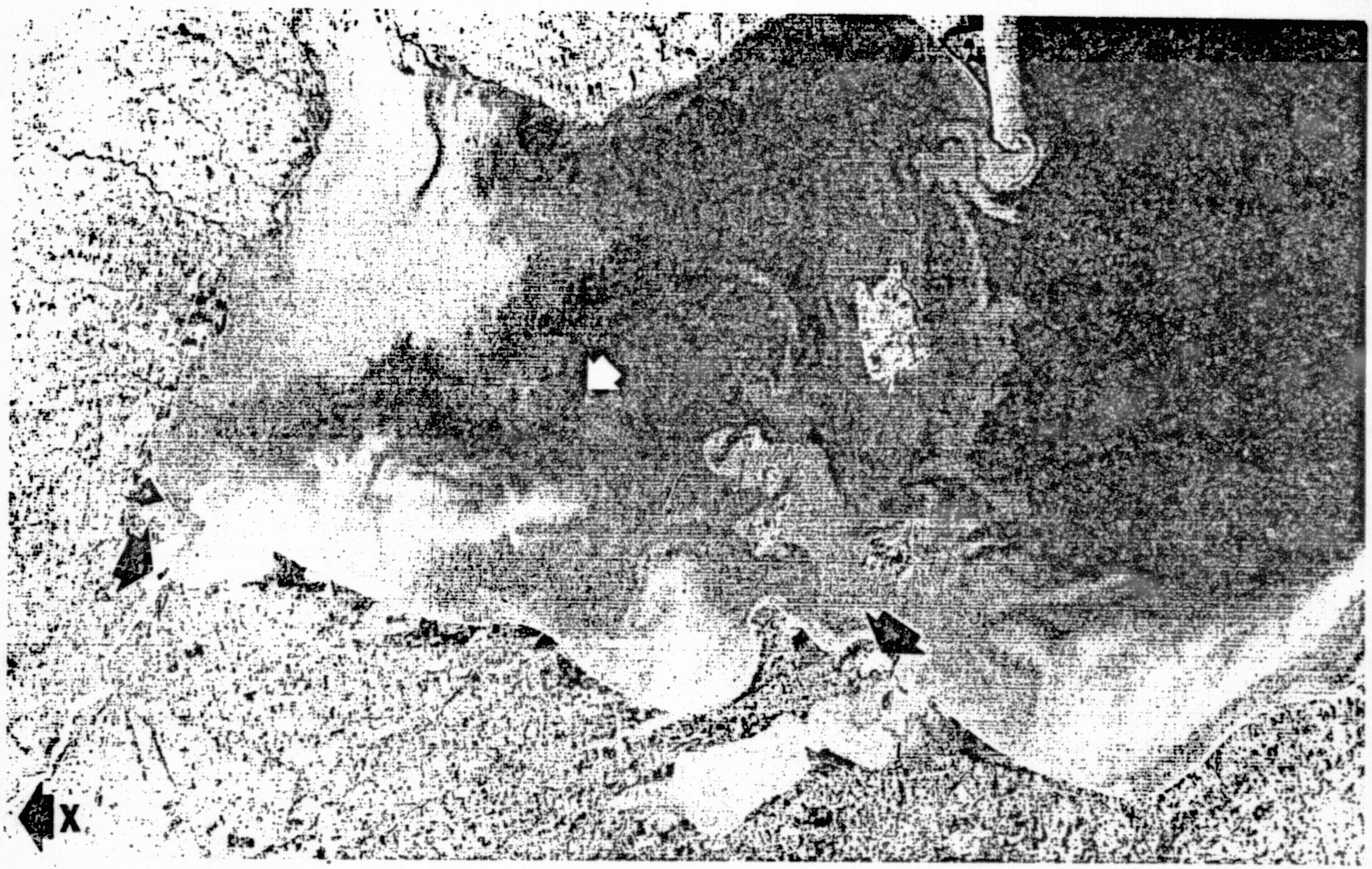


FIGURE 13. PORTION OF A LANDSAT SCENE (BAND 5, APRIL 14, 1973) SHOWING SUSPENDED SEDIMENTS IN THE WESTERN BASIN OF LAKE ERIE

Arrows indicate film transmissivity measurement points. Arrow with X indicates approximate location of USGS Water Quality Monitoring Station at Waterville, Ohio.

Results

The results of the LANDSAT data transmissivity analysis are contained in Table 3. The USGS-acquired hydrologic data used in the correlative analysis are shown in Table 4. The latter includes sediment discharge in tons per day measured at the Waterville Water Quality Monitoring Station. Plotting and comparing the 1975-1976 data shows agreement between the sediment discharge in the Maumee River and the percent transmissivity readings for all data with the exception of December 1975 and June 1976 (Figure 14). A similar lack of agreement was found between the 1973 LANDSAT and sediment discharge data (Figure 15).

It was observed that LANDSAT Band 6 is the best single band for identiffcation of sediment loads in water bodies.

Conclusions and Recommendations

A better correlation of data exists for the 1975-1976 data than for the 1973 data. The better data may have resulted from the following:

- Film transmissivity readings were not taken at the point where sediment load and discharge were measured. The size of the river on the small-scale imagery and the larger spot size of the densitometer precluded any film measurements on the river.
- As the sediment-ladened water enters the mouth of the bay the river velocity slows and the capacity of the river to carry particles (especially larger particles) in suspension lessens. This results in a dropping of sediment at the mouth of the bay or a short distance upstream from the mouth of the bay. Thus, a high sediment load in the river may not be reflected in the sediment levels of the bay and, in turn, the basin.
- Sediment levels in the bay and the basin may differ in amount as a result of the influence of wind. This may cause areas of erosion along the shore to influence sediment levels in the two areas differentially.

TABLE 3. PERCENT TRANSMISSIVITY READINGS OBTAINED FROM SELECT LANDSAT BAND 6 IMAGERY USING THE MACBETH DENSITOMETER

1973 Imagery	Density Step	Marblehead Quarry	Bay	Basin
27 Mar 73	0.8	4.5	2.0	0.85
14 Apr 73	0.7	6.0	1.4	1.25
7 June 73	0.7	4.0	1.7	0.73
25 June 73	0.56	11.0	3.0	1.25
18 Aug 73	0.55	6.0	1.55	1.3
23 Sept 73	0.8	0.625	1.38	0.69
11 Oct 73	0.7	2.3	1.0	0.69
1975-1976 Imagery	**Density Step**	**Marblehead Quarry**	**Bay**	**Basin**
19 May 75	0.4	20.0	5.0	0.7
6 June 75	0.25	35.0	13.0	1.9
30 July 75	0.4	23.0	3.9	1.05
10 Oct 75	0.53	Clouds No Reading	0.6	0.6
15 Nov 75	0.8	4.0	0.67	0.75
3 Dec 75	0.8	Clouds No Reading	0.95	0.95
7 Apr 76	0.49	23.0	4.8	1.8
18 June 76	0.6	35.0	9.0	4.5
6 July 76	0.6	26.0	2.9	1.9

TABLE 4. HYDROLOGIC DATA MEASURED AT THE WATERVILLE WATER QUALITY STATION FOR LANDSAT OVERPASS DATES IN 1973 and 1975-1976

1973	Mean Water Discharge, cu ft/sec	Sediment Discharge, tons/day
27 Mar 1973	17,500	7,280
14 Apr 1973	8,950	2,010
7 June 1973	27,800	36,500
25 June 1973	2,420	203
18 Aug 1973	5,120	1,130
23 Sept 1973	236	30
11 Oct 1973	610	87

1975-1976	Mean Water Discharge, cu ft/sec	Sediment Discharge, tons/day
19 May 1975	1,920	301
6 June 1975	13,600	10,400
30 July 1975	504	109
10 Oct 1975	770	79
15 Nov 1975	1,900	139
3 Dec 1975	10,400	3,850
7 Apr 1976	2,630	178
18 June 1976	596	50
6 July 1976	1,460	300

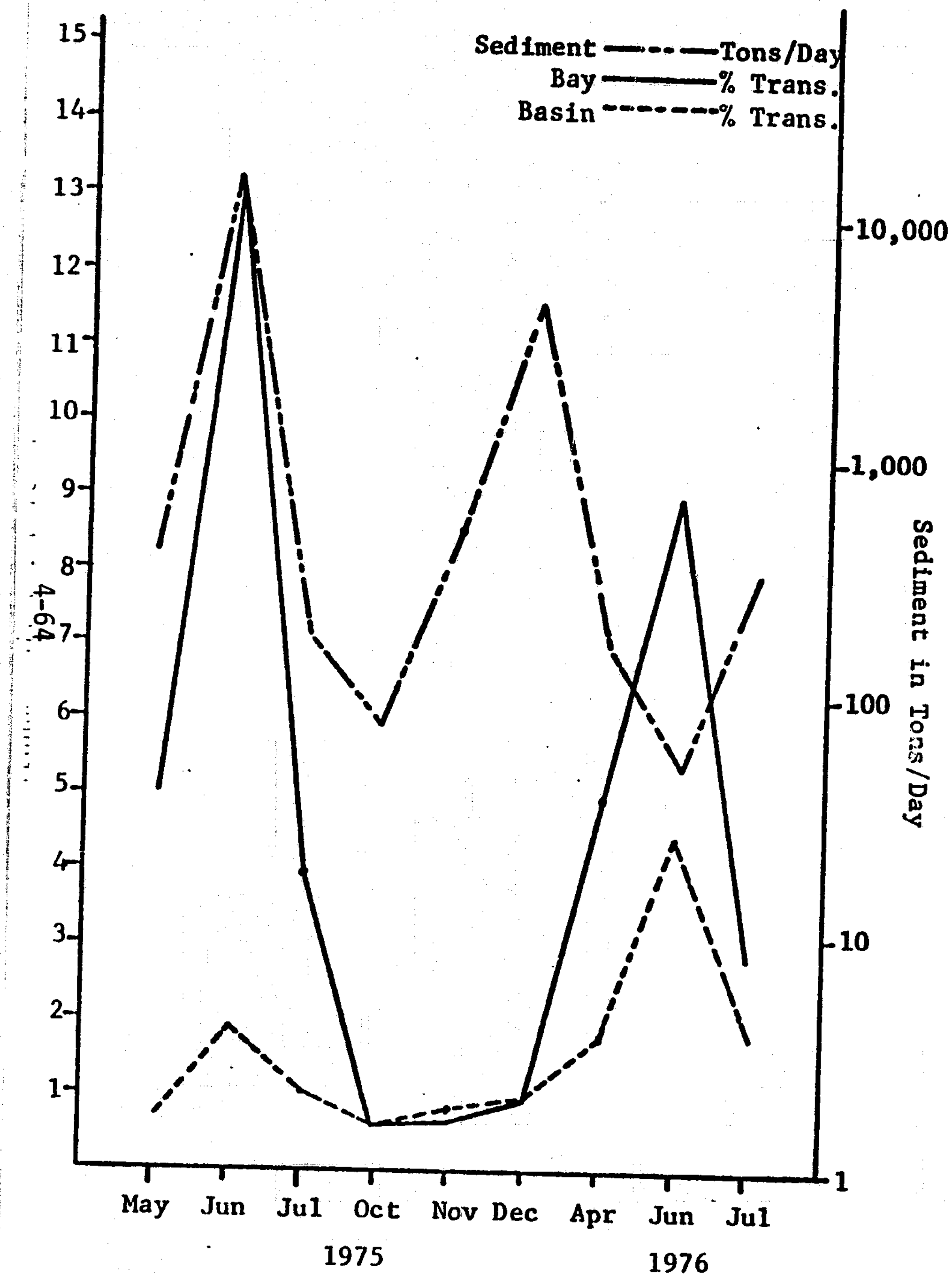


FIGURE 14. COMPARISON OF SEDIMENT DISCHARGE DATA AND FILM TRANSMISSIVITY MEASUREMENTS FOR LANDSAT 2 IMAGERY

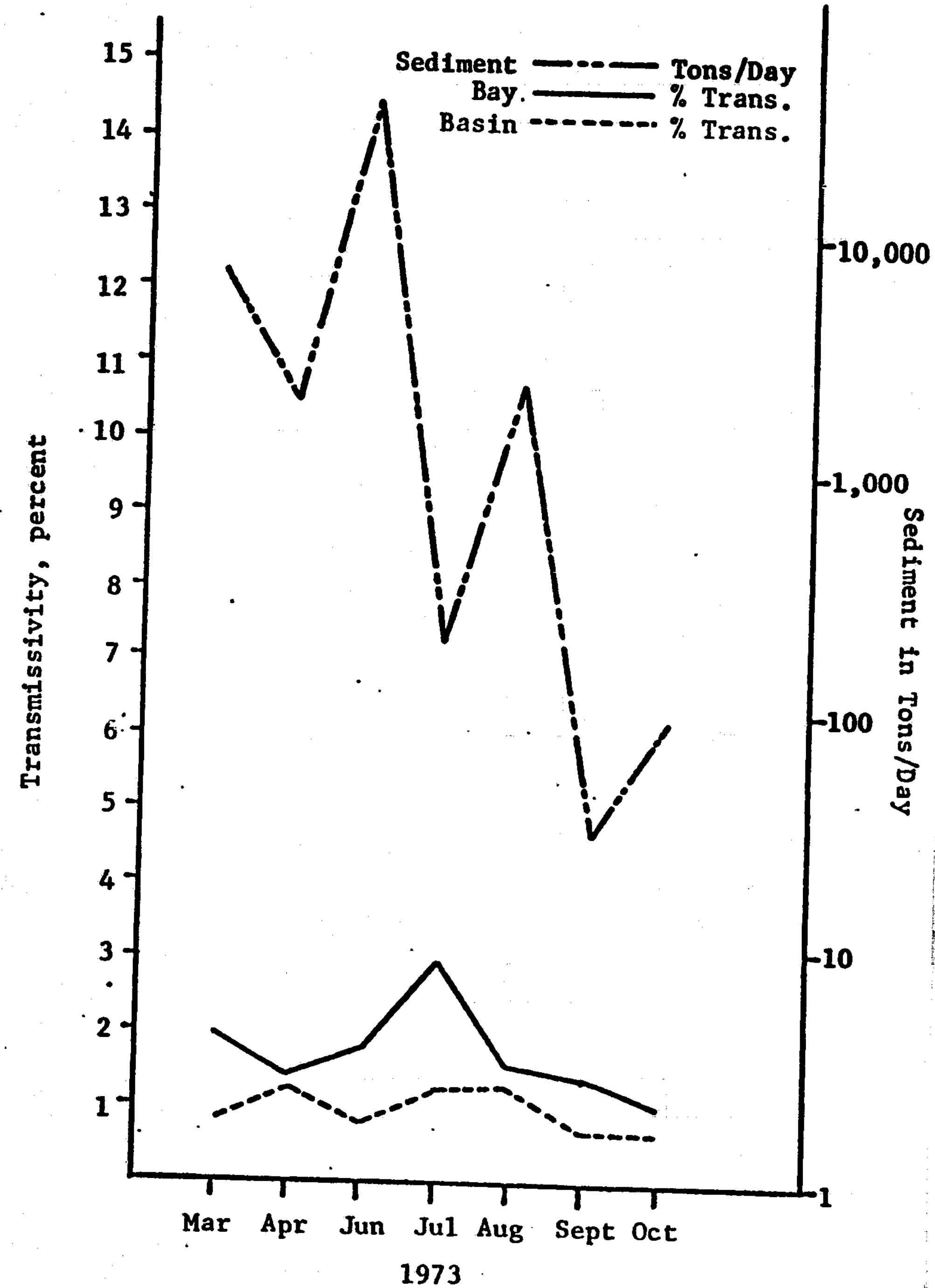


FIGURE 15. COMPARISON OF SEDIMENT DISCHARGE DATA AND FILM TRANSMISSIVITY MEASUREMENTS FOR LANDSAT 1 IMAGERY

352

Sufficient positive correlation has been found in the analysis to suggest a feasible method of using repetitive LANDSAT data to identify and measure suspended sediment levels in water bodies on a routine basis. However, more extensive analysis should be performed in order to establish measurement accuracies before any operational consideration is given to this technique and resultant data.

In addition, ground truth measurements of sediment levels and types of sediment material must be sampled at the same time as LANDSAT overpasses occur. These should be accompanied by spectral radiometric measurements in the same area. A complete and continuing survey program incorporating meteorological, hydrological, and environmental data could establish and document the link between river and lake conditions/characteristics required for developing a useful operational model.

Use/User Implications

A number of researchers have determined that LANDSAT imagery can be used for determining types and quantities of sedimentation in large reservoirs and lakes. This preliminary task has attempted to determine the feasibility of using the data for monitoring/modeling Lake Erie sedimentation by comparing the measurable reflectivity of sediments in the lake water as recorded on LANDSAT imagery with hydrological/sediment loading data.

Additional and more extensive research efforts are expected to clarify uncertainties experienced in this brief analysis and result in the development of a methodology for operational use.

Bibliography

"Water Resources Data for Ohio, Water Year 1975; Volume 2, St. Lawrence River Basin", U.S. Geological Survey Water-Data Report OH-75-2.

Anttila, P. W., and Tobin, R. L., "Fluvial Sediment in Ohio", U.S. Department of the Interior, Geological Survey, Open File Report 76-575 (August 1976).

Yarger, H. L., and McCauley, J. R., "Quantitative Water Quality with LANDSAT and Skylab", in Proceedings of the NASA Earth Resources Symposium, Houston, June 1975, Volume I-A, Report NASA-TM-X-58168, p. 347.

Gervin, J. C., and Marshall, M. L., "A LANDSAT study of Water Quality in Lake Okeechobee", in Proceedings of the American Society of Photogrammetry, Fall Convention, Seattle, September 28-October 1, 1976, p. 451.

Cater, C. H., "Natural and Manmade Features Affecting the Ohio Shore of Lake Erie", Ohio Department of Natural Resources, Division of Geological Survey Guidebook No. 1 (1973).

Rogers, R. H., et al., "Computer Mapping of Water Quality in Saginaw Bay With LANDSAT Digital Data", Proceedings of the American Society of Photogrammetry, Washington, D. C., February 22-28, 1976, pp 584-596.

TASK 3. LANDSAT AND AIRCRAFT URBAN LAND USE ANALYSIS OF COLUMBUS/ FRANKLIN COUNTY, OHIO

TASK 3. LANDSAT AND AIRCRAFT URBAN LAND USE ANALYSIS OF COLUMBUS/ FRANKLIN COUNTY, OHIO

Background

The Ohio LANDSAT 1 program domenstrated that many state-level requirements for land use planning could be served by repetitive, small-scale, multispectral satellite data. It was equally apparent that much of the high-priority need for monitoring land use changes, inventorying critical environmental areas and assessing land capabilities is associated with detailed natural and cultural features in large, dynamic and complex urbanized areas. This need cannot be completely fulfilled by the current LANDSAT data capabilities. However, until survey satellites which have significantly improved spectral and spatial capabilities are launched, high-altitude aircraft data could be a cost-effective alternative for reinforcing LANDSAT analysis in complex urbanized areas. Hence, the theme of this task was to determine the limits of LANDSAT land use data analysis in urban areas and the opportunities for merging detailed aerial data into a computerized land use inventory system to provide the detail and overall accuracies sufficient to permit its operational implementation on a state level.

Objective and Scope

The main objective of this task was to demonstrate how high-altitude aircraft data could be used to complement LANDSAT land use data analysis in large, complex urban areas of Ohio.

This land use demonstration analysis was conducted for the Columbus/Franklin County, Ohio, area. The site was selected for the following reasons:

(1) The area has experienced dynamic changes throughout the past 20-year interval

(2) The area contains a good mix of cultural, natural and environmental features such as heavy industries, large warehouse centers, an intensive transportation network, several rivers, reservoirs, old and new residential neighborhoods, airfields, etc.

(3) Local knowledge of the area would facilitate interpretation of LANDSAT and aircraft data

(4) The area has been extensively documented with aircraft, Skylab and LANDSAT imagery, allowing a multilevel/multidate/multiscale examination of land use features at image scales ranging from 1:40,000 to 1:1,000,000

(5) An initial (LANDSAT 1) study had already determined the general degree that land use features could be identified in this area.

Methodology

The task was accomplished in the following steps:

- Selection of map scales
- Selection of a suitable land use classification scheme and appropriate land use classes
- Acquisitions of base maps and data base
- Selection of mapping procedures
- Extraction of land use information from high-altitude aircraft imagery
- Computer analysis of LANDSAT digital data (CCT's)
- Comparison of LANDSAT and high-altitude aircraft land use data.

Selection of Map Scales

Map scales were selected by the participating staff of the Ohio Department of Natural Resources. A 1:24,000 scale was selected as the one of operational interest. At this scale, an area covered by a 1.2 acre pixel is represented on the map as an area of 0.36 by 0.36 cm (0.14 by 0.14 in.).

Selection of Land Use Classification Scheme and Classes

The USGS land use classification scheme used in the Ohio LANDSAT 1 program was selected by the project monitor at the Ohio Department of Economic and Community Development (ODECD) as desirable for this task also. However, certain modifications suggested by Ohio Department of National Resources personnel were made to better accommodate the subsequent digitization of land use data for incorporation in the State of Ohio land use inventory.

Also, the recently revised version of the USGS classification scheme was used, which changed some second-level feature classifications.

Acquisition of Base Maps and Data Base

Black and white Mylar base maps of Franklin County, Ohio, were purchased from the Ohio Department of Transportation. The Mylar maps were duplicates of base maps used in the compilation of the 1:24,000 USGS topographic mapsheets. Eighteen maps were required to cover the entire county; however, five maps were found to cover the Columbus metropolitan area.

Information on these base maps already featured transportation networks, schools, churches, rivers and reservoirs, as well as the location of the total urban outline in black. The most recent revision on these maps had been made in 1973.

The principal data used were six color infrared 240-mm format transparencies flown by NASA over Columbus, Ohio, on August 18, 1976. The film frames were totally cloud-free and generally appeared to be of excellent quality.

In addition, the following data were used:

- 1:40,000-scale, color and color IR imagery flown by NASA over Columbus in August 1973 and January 1974
- 1:1,000,000-scale MSS transparencies obtained over Columbus from 1973-1976
- CCT data of Scene E-1265-15483 dated April 14, 1973.

Selection of Mapping Procedures

Several techniques were evaluated for interpreting and transferring land use information to the 1:24,000-scale Mylar base maps.

Spectral Analysis or Density Slicing of the Color Infrared Transparency. A Spatial Data 703-32 Color Video system was used to determine whether Levels I and II land use features appeared spectrally distinct, so as to permit machine classification of the film data. The intent was to eliminate extensive photointerpretation time by using machine-aided techniques.

Digitization of the Color Infrared Imagery. A digitization system with a subroutine called Digitline/Digit 3D was evaluated. By mounting the positive transparency on the light table of the digitizer, or by projecting (and enlarging) it with a projector behind the light table, an operator could enter x, y and constant coordinates which marked the boundaries of each land use class. By entering sufficient points along each boundary, areas of Level I and Level II land use classes would then be recorded on magnetic tape for subsequent calculation of the overall boundary and plotting of a land use map. The intent was to generate land use data in computer-compatible formats which would eventually be entered into the statewide Ohio land use inventory. The problem with this method was that it proved entirely too time consuming. Also, polygons, rather than the precise boundaries, were marked, so that the areas covered by various land use categories were approximations, rather than the actual delineated areas.

Rear Projection to 1:24,000 scale of the Infrared Color Imagery Directly Onto the Mylar Base Maps. The color infrared imagery appeared superimposed on the Mylar maps and the photointerpreter delineated each land use class in color. A 240-mm rear projection system featuring a 1.5 by 2-meter screen was used to enlarge the 1:120,000-scale imagery 5X.

Extraction of Land Use Information from High-Altitude Aircraft Imagery

The rear projection techniques were found to be suitable for identifying and delineating detailed land use classes, and for transferring these to a 1:24,000-scale map. Each 240-mm infrared color transparency was mounted in the rear projection system and projected in full format on the 1.5 by 2-meter rear projection screen (approximately 5X magnification). Each Mylar base map was then fastened on the screen and the projection optics were adjusted until the projected infrared imagery and the map perfectly coincided. Major road intersections were used as alignment reference points. The image analysts then outlined each land use class on the Mylar base maps. Certain features, such as water, forest land, and new construction, could be identified on the basis of image color or tone. Land use

features, such as industry, commercial, and residential areas, required identification on the basis of spectral and spatial characteristics, i.e., on the basis of their geometry, size, alignment, etc., as well. If industrial and commercial complexes could have been classified together, then some of the detailed work expended in this effort could have been reduced. Specifically separation of industrial and commercial features required a stereo analysis of 1:40,000-scale imagery. Only in one instance was a ground check necessary to confirm the interpretation. The Spatial Data Color Video System 703-32 was used to density slice several land use classes which could be accurately differentiated on the basis of their spectral characteristics.

Basically, land use classes were delineated according to the current USGS classification system. The following classes were added, however, to be responsive to expressed local planning interests:

- Areas undergoing construction, to indicate where structures were in the process of being built, but were not yet completed. The Level II class was added to indicate areas of current growth/development.
- Public and private institutions, such as schools, universities, and churches.
- Public and private recreation, such as parks and golf courses.

During the aircraft imagery analysis, comparison was made with a detailed (1:50,000 scale) land use map compiled and published by the Franklin County Regional Planning Commission in 1964. Discrepancies occurred only in areas having undergone changes and in areas where the Planning Commission probably delineated land use boundaries from reference data other than on aerial imagery.

Each land use interpretation was transferred to the 1:24,000-scale Mylar base map with a color pen for subsequent planimeter analysis.

Computer Analysis of LANDSAT CCT Data*

For comparison purposes, LANDSAT computer compatible tapes of April 12, 1973, data showing the Columbus metropolitan area were analyzed to determine to what extent land use class Levels I and II could be

* This effort was performed in concert with and at the Battelle Northwest Laboratories.

differentiated. A hands-on, interactive computer system was used, which provided on-line evaluations of complex data sets, provided for the rapid input of calibration data, and for the addition of data during and after the analysis sequence. The digital tape data were read directly into the computer system, after converting the 7-track CCTs to 9-track tape. The computer system had a 128 K core memory, a 20 million word disk storage which allowed for the rapid manipulation of the data. A high-resolution graphic digitizer was used to input high-altitude color infrared imagery and cartographic data. In addition, the system had a light pen interactive scope, high-resolution storage scope and, for output devices, a multipen Calcomp plotter, a Gould electrostatic plotter/printer for producing gray level coded maps and plots, and a DICOMED high-resolution color film recorder. These peripherals allowed a wide range of user products to be reproduced rapidly.

Emphasis was placed on producing color land use maps with the DICOMED system, which was used to produce 80 by 80-mm color negative acetate film transparancies on a 4 by 5-in. film format. The transparency was produced with a 4096 by 4096 point resolution, using three color filters. Analysis was initially performed for 12 spectral classes which were eventually compressed to nine land use classes.

The rationale for producing the various outputs was derived for a variety of reasons. They were to:

- Provide the image analysts with the means to make qualitative and quantitative comparisons and correlations with standard cartographic data and with the data derived from the high-altitude aircraft data
- Provide information as to the limitations imposed by each product, when urban land use classifications were performed
- Provide visual proof if the use of the CCT's definitely resulted in more land use information, and to a greater detail than the image transparencies
- Help determine which type of product was more appealing to the land use planner when making decisions based on relatively complex information
- Help establish those land use classes which could be derived with confidence from LANDSAT data, and those which result in poor accuracy figures.

Comparison of Land Use Data Derived From LANDSAT and Aircraft Data

A comparison of land use data extracted from the high-altitude color infrared aircraft and the LANDSAT data was made. The intent was to determine to what extent/accuracy Level I and II land use classes could also be extracted from LANDSAT data. For detailed comparison one USGS quadrangle sheet (scale 1:24,000; area = 145 km^2) was analyzed.

Area data were calculated from the LANDSAT data by computer. Land use information derived from the aircraft imagery was delineated with a K&E 62000 Polar Planimeter, and acreages calculated.

Results

In-depth analyses of high-altitude aircraft imagery, LANDSAT CCT data and imagery generated from the CCT's of the Columbus/Franklin County, Ohio, area yielded a number of interesting results.

High-altitude color infrared imagery, photoscale 1:120,000, with an estimated spatial resolution of 1-5 meter, was useful for delineating all Level I land use classes applicable to Ohio. It was also used to derive 17 out of 18 Level II land use classes. Larger scale aircraft imagery and ground truth data were required to separate some classes, especially where industrial and commercial features appeared side by side. This effort resulted in the preparation of four Mylar maps (scale 1:24,000) covering the total metropolitan area of Columbus, Ohio. The maps show Level I and II land use classes and will be scan-digitized by the Ohio Department of Natural Resources for entry into the statewide land use inventory for demonstration purposes. (See Figure 16 for sample of map products generated.)

Computer-processed LANDSAT data were used for delineating all Level I land use classes applicable to Ohio. They were also used to derive eight Level II land use classes with varying degrees of accuracy. In addition, the following computer-generated outputs were prepared and utilized in this study:

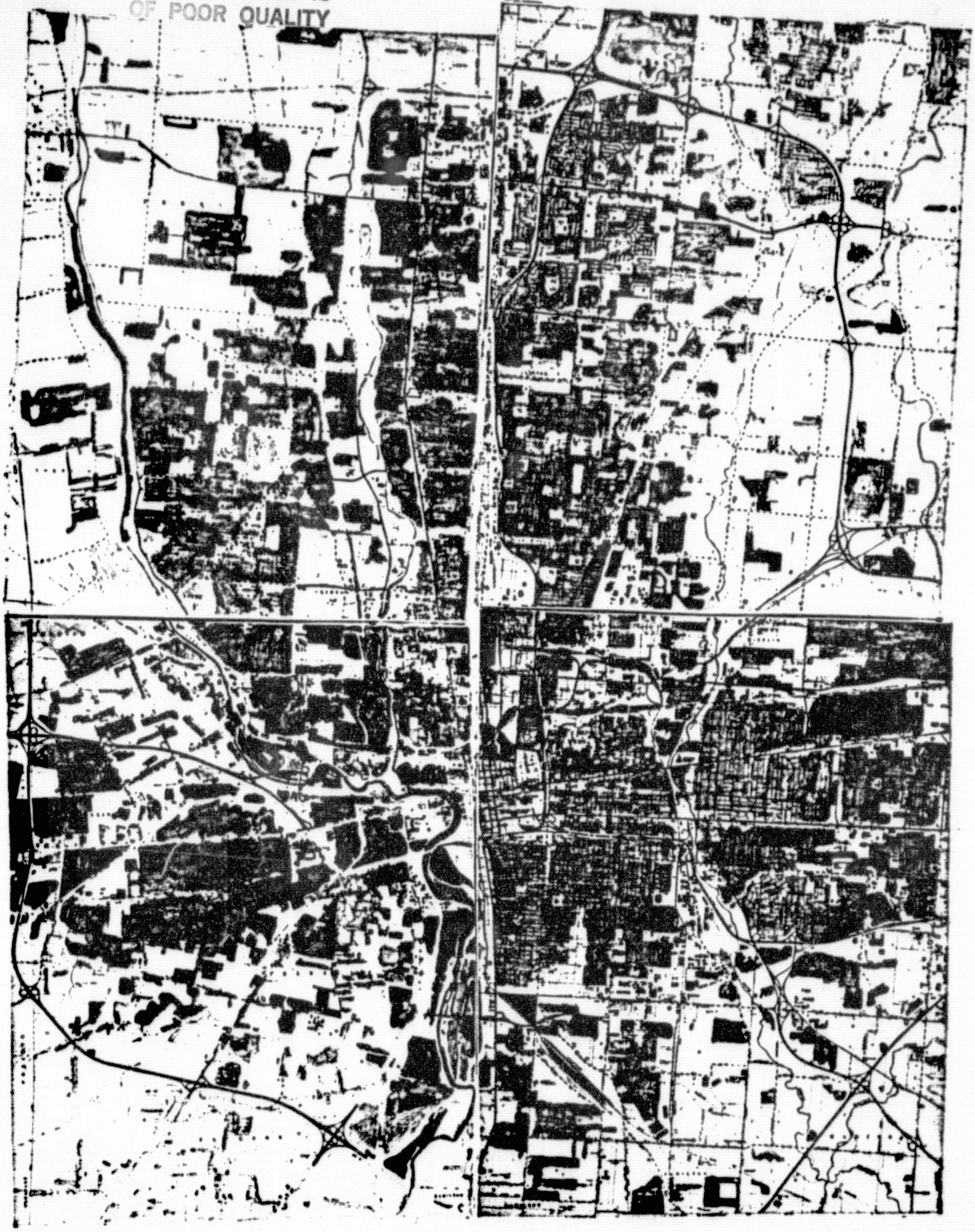


FIGURE 16. COLOR-ENCODED LAND USE MAPS OF COLUMBUS, FRANKLIN COUNTY, OHIO BASED ON CONVENTIONAL, PHOTOINTERPRETIVE ANALYSIS OF AIRCRAFT DATA (MOSAIC OF FOUR USGS QUAD SHEETS, ORIGINAL SCALE 1:24,000)

(1) Hardcopy printouts which show Franklin County and surrounding area as a color composite of the four LANDSAT MSS bands 4, 5, 6, and 7. (0.5-0.6; 0.6-0.7; 0.7-0.8; and 0.8-1.1 μm, respectively). The scene was recorded by LANDSAT 1 on April 12, 1973. LANDSAT 1 data were used since CCT data for LANDSAT 2 were not available. The color composite printout was scaled to 1:125,000 (Figure 17).

(2) Hardcopy printouts of land use features appearing in the LANDSAT scene above, bounded by the Franklin County outline. Nine Level I and II land use classes were shown in color. The printout was scaled to 1:125,000 (Figure 18).

(3) Hardcopy printouts of area calculations for the Franklin County acreages covered by each land use class (Figure 19).

(4) Hardcopy printouts of land use features appearing in the area of one USGS quadsheet (1:24,000) in the Northeast portion of Franklin County. It was color encoded in the same land use classes as the land use printout of the entire county. Again, the same nine classes were used (Figure 20).

(5) Hardcopy printouts of area calculations for the county Northeast quatrant acreages covered by each land use class (Figure 21).

(6) A gray tone map using only MSS Band 6, scaled to 1:24,000, of Franklin County.

(7) A symbol encoded map using only MSS Band 6, scaled to 1:24,000, of Franklin County, showing 12 land use classes.

A comparison of high-altitude aircraft and LANDSAT data showed that LANDSAT data are adequate for delineating land use areas in rural areas and in the new growth sections of urbanized areas. This implies that, within a state like Ohio, land use classification by LANDSAT data is feasible for 98.5 percent* of the state. Within the urban areas, especially those of the larger metropolitan areas such as Cincinnati, Columbus, and Cleveland, use of high-altitude aircraft data by conventional and/or computerized image analysis is essential. The reason for this is simply that rural and newly urbanized areas may be identified and delineated primarily on the basis of spectral data content, i.e., on the basis of the way they reflect sunlight in the visible and near infrared portions of the

---

* Figures from Ohio 2000, Choices for Today: Metropolitan Ohio, November 1974, ODECD p. 69.

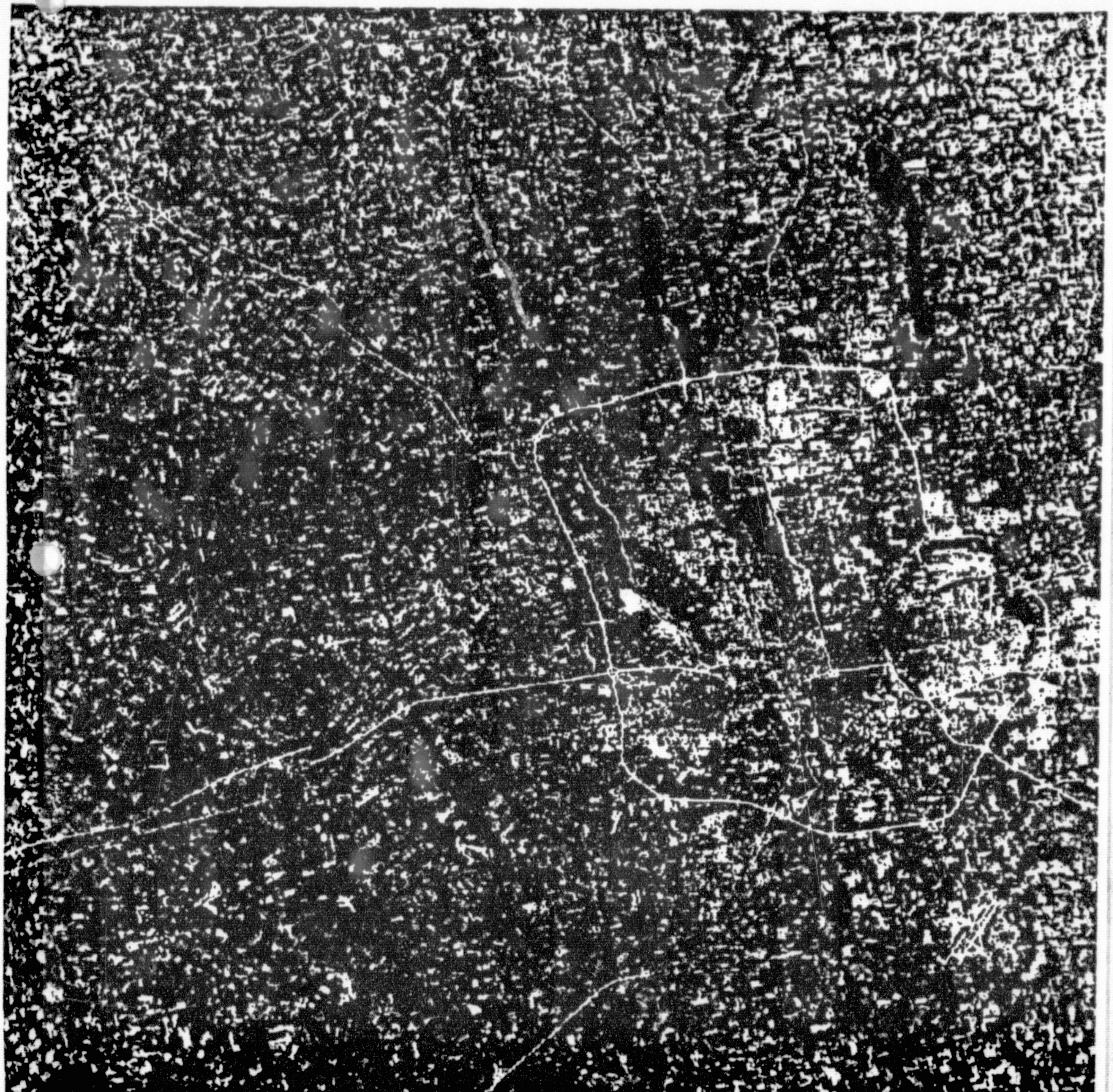


FIGURE 17. COMPUTER GENERATED COLOR COMPOSITE (4 MSS LANDSAT BANDS) OF COLUMBUS, OHIO AND SURROUNDING AREA. (DATA TAKEN BY LANDSAT 1 ON 4-12 1973)

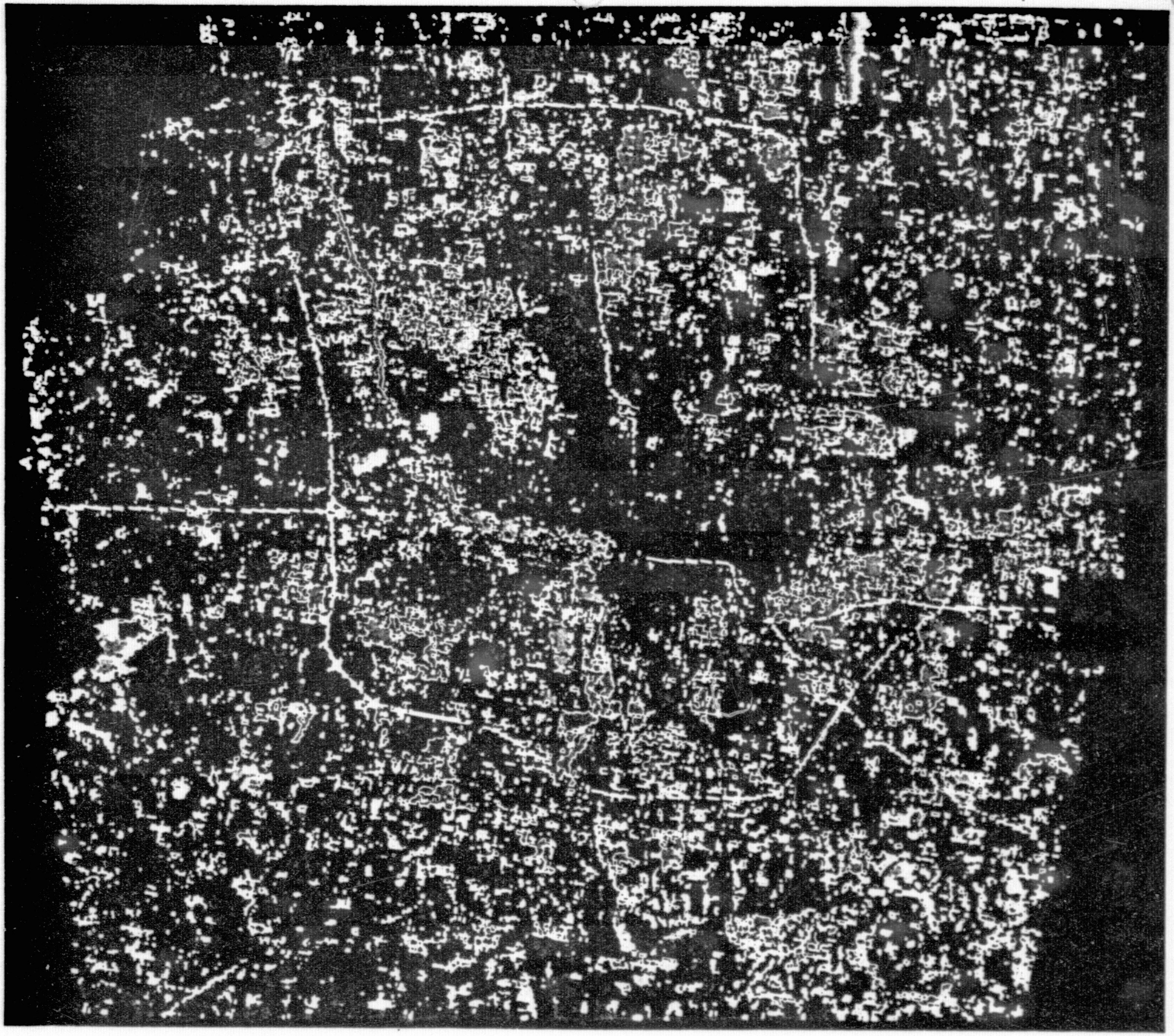
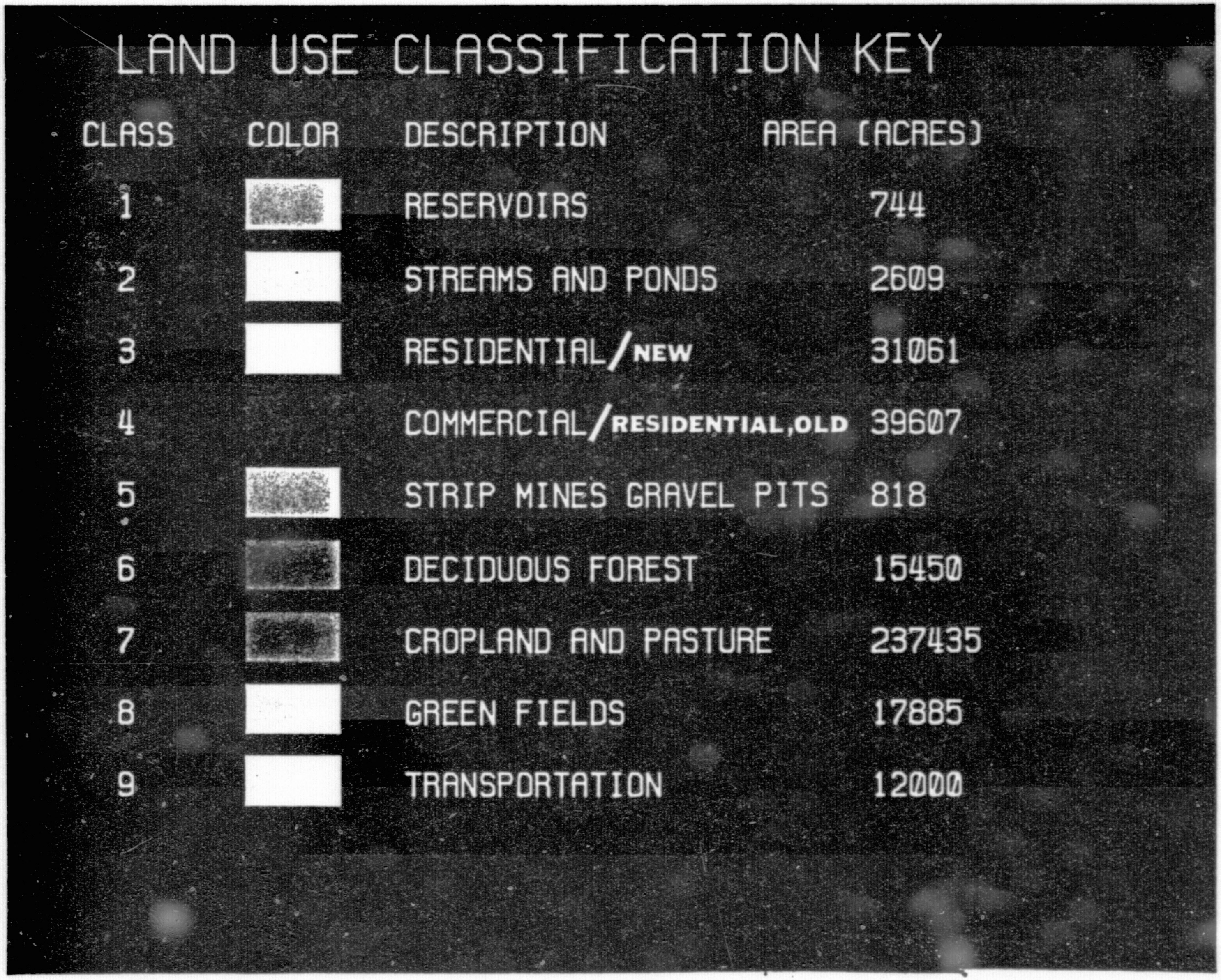


FIGURE 18. COMPUTER GENERATED, LAND USE MAP OF FRANKLIN COUNTY, OHIO (1359 SQ KM). DATA ARE ESPECIALLY WELL SUITED FOR DELINEATING NEWLY URBANIZED AREAS. ANALYSIS OF EARLY SPRING (APRIL 12) DATA, RESULTED IN POOR CLASSIFICATION OF OLDER, ESTABLISHED NEIGHBORHOODS.

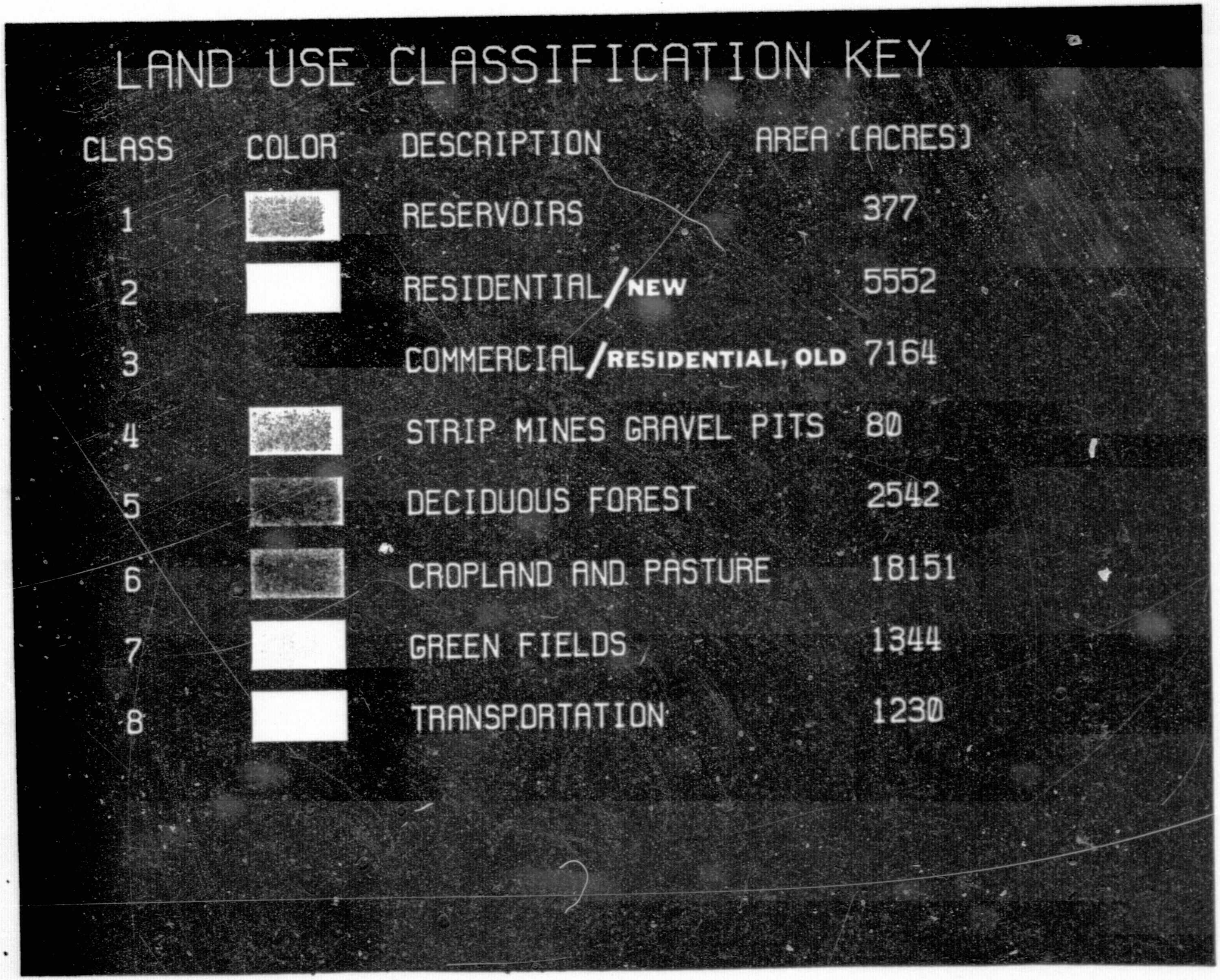


LAND USE CLASSIFICATION KEY

CLASS	COLOR	DESCRIPTION	AREA (ACRES)
1		RESERVOIRS	744
2		STREAMS AND PONDS	2609
3		RESIDENTIAL/NEW	31061
4		COMMERCIAL/RESIDENTIAL,OLD	39607
5		STRIP MINES GRAVEL PITS	818
6		DECIDUOUS FOREST	15450
7		CROPLAND AND PASTURE	237435
8		GREEN FIELDS	17885
9		TRANSPORTATION	12000

FIGURE 19. COMPUTER LANDSAT LAND USE CLASSIFICATION KEY AND AREA STATISTICS FOR FRANKLIN COUNTY, OHIO

FIGURE 20. COMPUTER GENERATED, COLOR ENCODED LANDSAT LAND USE MAP OF 1 USGS QUAD SHEET (1:24,000 ORIGINAL SCALE) OF N.E. COLUMBUS, FRANKLIN COUNTY, OHIO



LAND USE CLASSIFICATION KEY

CLASS	COLOR	DESCRIPTION	AREA (ACRES)
1		RESERVOIRS	377
2		RESIDENTIAL/NEW	5552
3		COMMERCIAL/RESIDENTIAL, OLD	7164
4		STRIP MINES GRAVEL PITS	80
5		DECIDUOUS FOREST	2542
6		CROPLAND AND PASTURE	18151
7		GREEN FIELDS	1344
8		TRANSPORTATION	1230

ORIGINAL PAGE IS OF POOR QUALITY

FIGURE 21. COMPUTER LANDSAT LAND USE CLASSIFICATION KEY AND ASSOCIATED AREA STATISTICS FOR N.E. COLUMBUS, FRANKLIN COUNTY, OHIO QUAD SHEET

electromagnetic spectrum. Within an established portion of a city, however, spectral signatures of Level II land use features and seldom unique and must be identified on the basis of spectral reflectivity and size, alignment, geometry, height, etc., i.e., their spatial characteristics. Table 5 identifies those land use classes which are extractable from LANDSAT data along with those which require aircraft data use. Table 6 was compiled during a detailed analysis of the primarily urbanized areas of Franklin County, Ohio. LANDSAT, high altitude and medium altitude aircraft data were analyzed. The table shows to what extent Level I, II, and III land use information can be (a) mapped (delineated by area) and (b) identified from LANDSAT data. It also lists the MSS bands which provide the best land use detail, and whether little or detailed correlation with aircraft data is required to identify a particular land use feature.

By comparing area mensuration data derived for an area covered by one USGS quad sheet in northeast Franklin County, a measure of accuracy was provided. Table 6 compares acreages in four Level I land use categories as measured by the computer with LANDSAT data and by conventional planimetry using the high altitude aircraft imagery. Using the aircraft mensuration data as a standard, LANDSAT data deviated by no more than 6.7 percent in an area of 145 square kilometers.

Conclusions and Recommendations

As a result of the very detailed land use analysis conducted of the Columbus/Franklin County, Ohio, area using satellite, aircraft and limited ground truth data, it was established that high-altitude infrared color photography is useful for analyzing urban land use to Level I and Level II detail and some Level III. One 240-mm-format image covers an area of 28 by 28 km, as compared with 2.8 by 2.8 km for the conventionally flown 1:12,000-scale imagery. The cost saving implications in terms of data collection and analysis time are obvious. It simply means that Franklin County, which requires more than 840 low-altitude photographs for total coverage, can be covered with six to eight high-altitude photographs. There is still certain land use information which requires larger scale aircraft data, such as evidenced in industrial and commercial areas. However, most

TABLE 5. OVERVIEW OF LANDSAT AND AIRCRAFT LAND USE DATA EVALUATION OF FRANKLIN COUNTY, OHIO

Land Use Code[a]	Land Use Class	Land Use Level	Can Be Mapped From LANDSAT[b]	Can Be Identified From LANDSAT[c]	Best MSS Band[d] (in order)	Requires High Altitude CIR[e] (minimum;maximum)	Accuracy[f]	Comments
1	Urban and built-up	I	Yes	Yes	5; composite	No	95%	Can be confused with surface mining, therefore notation of geographic location is important during image analysis (minimum area 1-10 hectares).
11	Residential	II	Yes	Yes	5; composite	Yes; minimum-maximum		Best results in new areas, where new buildings, new concrete street surfaces, poor on recently established lawns, and sapling trees 3-5 meters high result in vivid, bright spectral signature. Older neighborhoods, because of surrounding established vegetation and trees 10-20 meters high, are often confused with parks, forestland and open space. Residential areas in core of city are virtually masked by surrounding dense street patterns, commercial, industrial and other structures.
111	New	III	Yes	Yes	5; composite	Minimum		
112	Old	III	Yes	No	5; composite	Yes, maximum		
113	Urban core	III	Yes	No	5,7, composite	Yes, maximum		
12	Commercial	II	Yes	No	5; composite	Yes; maximum		Large shopping centers of 5 hectares and more.
13	Industrial	II	Yes	No	5; composite	Yes; stereo maximum		Large plants of 10 hectares and more.
14	Transportation	II	Yes	Yes	5,7; composite	No		New major highways and airports are best seen in MSS Band #5. Older, 1st and 2nd order asphalted streets in urban area best seen in MSS Band #7.
15	Industrial & commercial complexes	II	Yes	No	5; composite	Yes; maximum		Requires areas of 5 hectares and more for delineation of features.
16	Mixed urban and built-up	II	Yes	Yes	5; composite	No		

TABLE 5. (Continued)

Land Use Code[a]	Land Use Class	Land Use Level	Can Be Mapped From LANDSAT[b]	Can Be Identified From LANDSAT[c]	Best MSS Band[d] (in order)	Requires High Altitude CIR[e] (minimum;maximum)	Accuracy[f]	Comments
17	Other urban Built-up land	II	Yes	Yes - no	5; composite	Yes; minimum-maximum		
171	Areas undergoing active con-struction	III	Yes	Yes	5; composite	No		Very vivid spectral signature. Des-cribes areas in process of building up. Areas as small as 1/2 hectare have been identified.
172	Areas of new urban growth	III	Yes	Yes	5; composite	No		Describes areas which were built up in the last 10-15 years. Vivid spectral signature.
173	Public and private recreation	III	Yes	No	5,7; composite	Yes, minimum		Describes golf courses, parks. Golf courses are rarely confused with other land use features, but parks can be confused with forestland and open land.
174	Institutional	III	No	No	5; composite	Yes, maximum		Universities, schools, churches
2	<u>Agriculture</u>	I	Yes	Yes	5,7; composite	No	92%	Readily identifiable land use fea-ture. Best identification during growing season.
21	Crop land and pasture	II	Yes	Yes	5,7; composite	No		Identifiable by "checkerboard" pattern during plowing season. Re-quires fields of 5 hectares minimum for mapping.
22	Orchards, groves, etc.	II	No	No	None	No		Spectral resolution insufficient in LANDSAT and high-altitude A/C imagery. Requires 1:40,000-scale imagery and larger.
24	Other agri-cultural land	II	Yes	Yes	5; composite	No		Plowed fields provide vivid spectral signature.
4	<u>Forest</u>	I	Yes	Yes	5; composite	No	93%	Identifiable in all seasons.
41	Deciduous forest	II	Yes	Yes	5; composite	No		Identifiable during growing seasons.
42	Evergreen forest	II	Yes	Yes	5; composite	No		Identifiable during all seasons and especially during winter months.
43	Mixed forest	II	Yes	No	--	Yes; maximum		Ability to identify mixed deciduous and evergreen forest requires high-altitude aircraft imagery, unless for-est contains pure stands of 5 hectares minimum of either forest type.

TABLE 5. (Continued)

Land Use Code[a]	Land Use Class	Land Use Level	Can Be Mapped From LANDSAT[b]	Can Be Identified From LANDSAT[c]	Best MSS Band[d] (in order)	Requires High Altitude CIR[e] (minimum;maximum)	Accuracy[f]	Comments
5	Water	I	Yes	Yes	7,6; composite	No	90%	Identifiable in all seasons.
5.1	Streams and canals	II	Yes	Yes	7,6; composite	No		Identification of water signature is a function of stream or canal width. Streams which are less than 10 meters in width may be identified in MSS Band 7 or by tree lines on banks of stream in MSS Band 5.
5.2	Lakes	II	Yes	Yes	7,6; composite	No		Lakes as small as 1 hectare have been identified.
5.3	Reservoirs	II	Yes	Yes	7,6; composite	No		
7	Barren land	I	Yes	Yes	5,7; composite	No		
75	Strip mines, quarries	II	Yes	Yes	5,7; composite	Yes; minimum		Differentiation among types of surface mines requires high-altitude aircraft.
77	Mixed barren land	II	Yes	Yes	5,7: composite	No		

(a) New land use and land cover classification system for use with remote sensor data developed by the U.S. Geological Survey (Circular 964, 1976). Supersedes Circular 671.

(b) Boundary of land use feature can be delineated by spectral or spectral and spatial characteristics, providing the feature occupies a specified minimum area.

(c) Land use feature can be positively identified (90% and better) from LANDSAT data.

(d) Land use feature may be observed in all four MSS bands, but these recorded the feature best (in order). Composites are compiled by combining two or more MSS bands, such as 5 and 7; 4, 5, and 7; and 4, 5, 6, and 7.

(e) Indictes whether land use feature requires use of aircraft data in addition to LANDSAT data for accurate delineation and/or identification.

(f) Accuracy determined in this study by comparing computer-processed LANDSAT data with high-altitude aerial color infrared imagery analysis.

TABLE 6. LAND USE AREA MENSURATION DATA CALCULATED FROM LANDSAT AND HIGH-ALTITUDE AIRCRAFT DATA
(LANDSAT Data Was Derived by Computer; Aircraft Data Was Obtained by Planimetry. Data Covers the USGS 1:24,000 Quadsheet of N.E. Columbus, Ohio)

Land Use Classification	Level	Area Calculated From LANDSAT (Acres)	Area Calculated From A/C (Acres)	Difference (Acres)	% Difference
Urban & Build-up Land	I	12,716	12,137	+579	4.8
Agriculture and Op[illegible] Land	I	19,495	21,127	+1,632	7.7
Forest	I	2,542	2,720	-178	6.5
Water	I	377	342	+35	9.8

weighted average = 6.7%

land use maps generated for Franklin County during the past 20 years could readily have been accomplished using high-altitude aerial data.

LANDSAT data are also suitable for land use analysis - provided analyses and interpretation are limited for Level I and selected Level II categories. This permits general land use classification of the bulk of rural and urban areas within the state at scales no larger than 1:250,000. Within complex urbanized areas, where land use planners require primarily Level II detail, LANDSAT data must be used on a more limited basis. For example areas which have experienced recent built-up or growth, as well as those undergoing construction, can be readily and accurately delineated on LANDSAT data. LANDSAT data are, therefore, ideally suited for updating older maps and for monitoring urban growth rates and directional trends. However, older, established urban areas require the kind of detail typically found in the high-altitude aircraft imagery.

Based on the above conclusions, it is recommended that a hand-in-glove analysis scheme be developed for simultaneously performing land use analysis using LANDSAT and high-altitude aircraft data. The LANDSAT data would be used primarily for providing general land use information in all rural and in newly urbanized and developing areas. High-altitude aircraft data would then be used to perform more detailed classification required primarily in the complex urban core, where spatial and spectral LANDSAT data will not suffice. Such a scheme is outlined in Figure 22. It should be noted that the scheme calls for the digitization of high-altitude aircraft data. Usually, digitization is a costly and sometimes time-consuming item. However, it is believed that the relatively few high altitude aircraft photographs required to cover an entire city, and the ability to handle the aircraft data in a common format with the LANDSAT data, justifies the added cost. Moreover, the time and cost required to perform manual data transfer by conventional methods make a computer analysis, with strong image analysis interaction, optimum.

A popular opinion of land use planners is that the spatial resolution of LANDSAT data should be greatly improved. Some suggest as much as one magnitude improvement to achieve a 1 to 10-meter resolution before operational use is practical. However, the findings of this task suggest

FIGURE 22 (Continued)

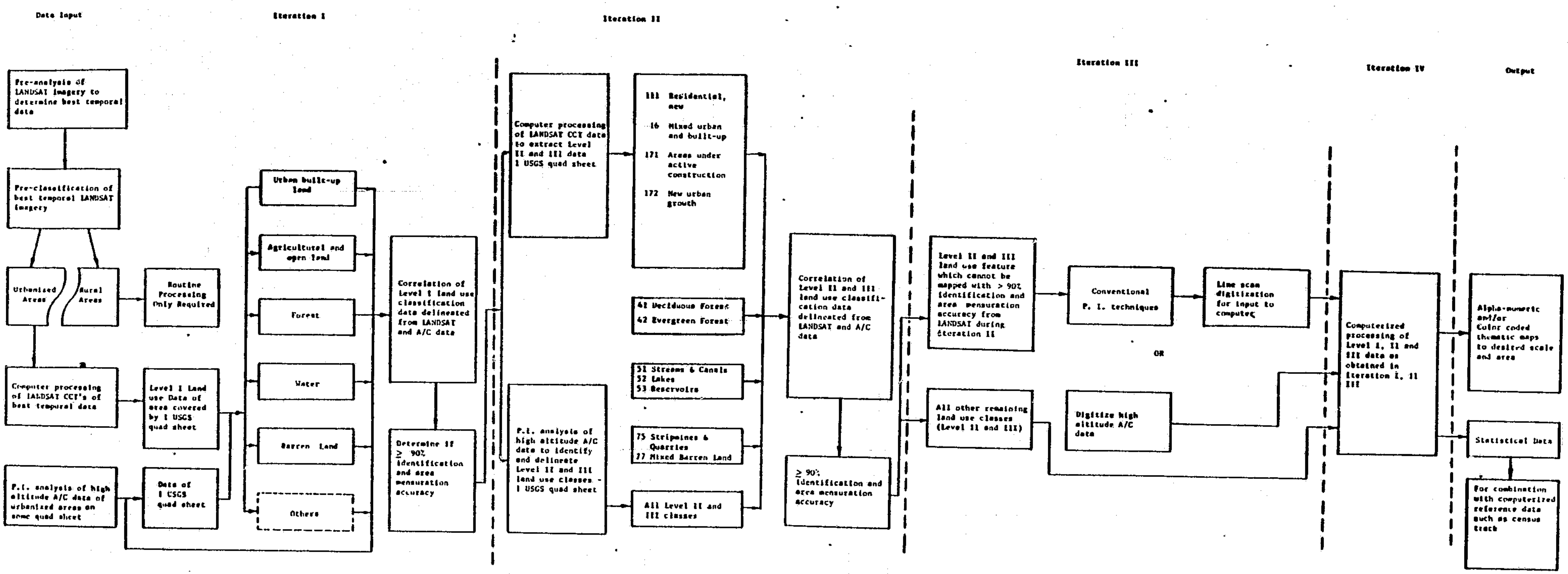


FIGURE 22. A SUGGESTED SCHEME FOR EXTRACTING URBAN LAND USE CLASSIFICATION DATA FROM LANDSAT AND A/C DATA

ORIGINAL PAGE IS OF POOR QUALITY

376

that the capacity to use LANDSAT data lies in the skillful use of the data as it is (or with planned improvements to 30 meters) but that it always be used in conjunction with high-altitude aircraft data.

Use/User Implications

The results of this study suggest that the current computerized statewide LANDSAT land use inventory of Ohio can be effectively and confidently utilized in non-urban areas and for selected land use planning interests (such as new growth) in the larger urbanized areas.

By incorporating detailed (Level II) land use features extractable only from aircraft data, as demonstrated for the Columbus/Franklin County area, operational use of the computerized inventory can be extended to all land use planning needs, including those in complex urbanized areas.

LANDSAT data user products in the land use area should emphasize the preparation of color-coded land use outputs which resemble thematic maps, rather than the black and white alphanumeric computer printouts, which are difficult to use.

Bibliography

"Relevance of ERTS 1 Data to the State of Ohio", Ohio Department of Economic and Community Development (October 1974).

"Utilizing Skylab Data in On-Going Resource Management Programs in the State of Ohio", Ohio Department of Economic and Community Development (November 1975).

Anderson, J. R., et al., "A Land Use and Land Cover Classification System of Use With Remote Sensor Data", U.S. Geological Survey Paper 964 (1976).

Proceedings of the American Society of Photogrammetry, Fall Convention, Seattle, September 28-October 1, 1976 (various items).

Proceedings of the NASA Earth Resources Survey Symposium, Houston, Texas, June 1975, Volume I-C, Land Use.

Nevius, W., et al., Ohio 2000, Choices For Today: Metropolatin Ohio, November 1974, 74 pages.

TASK 4. WOODLAND SURVEY OF NORTHEASTERN OHIO

TASK 4. WOODLAND SURVEY OF NORTHEASTERN OHIO

Background

Experiments conducted under the initial State of Ohio LANDSAT program (1972-1974) showed that it is feasible to conduct total forestland surveys in the State of Ohio. Analysis of LANDSAT imagery revealed that woodland areas of 5 hectares minimum size appear with a detail exceeding that typically found in 1:250,000-scale topographic mapsheets, and very closely approaching that of 1:24,000-scale maps. It was also concluded that "pure" stands of pines and hardwoods of at least 5 hectares stand size could be readily distinguished in color composite imagery.

Because of the interest expressed by the Ohio Crossroads Resource Conservation and Development (CRC&D) organization in using remote sensing to assist in the development of the timber industry in Northeastern Ohio, a follow-on investigation using Skylab S-190 A and B imagery was undertaken to determine the extent to which such critical parameters as stand size, maturity, and tree types could be identified. As the result of this effort, forest inventory maps of Trumbull, Mahoning and Columbiana Counties, Ohio, were prepared at map scales of 1:63,360 (1 inch = 1 mile). Forested areas as small as 2-5 hectares were delineated. The inventory determined that actual woodland areas were from 2 to 9 percent larger within the counties than had been reported in earlier surveys conducted in 1970. A second-level analysis determined that the following stages of forest growth could also be identified:

Mature timber
Intermediate and pole timber
Seedlings and saplings
Brushland
Cut/clear areas.

It also established that the following types of forest stands in these areas could be differentiated:

Softwood
Hardwood
Mixed
Cut
Brushland.

However, end-user personnel (CRC&D) emphasized their requirement for specific differentiation of tree types and woodland composition before their decision-making needs could be met. Since such information could not be satisfactorily derived from Skylab imagery, it was planned to determine the feasibility of using high-altitude aircraft imagery obtained during the LANDSAT follow-on program, with an improved spatial resolution of better than one magnitude over the Skylab imagery, to provide the necessary detail. There was an additional task interest: An in-depth study of LANDSAT (digital) data to determine whether such repetitive data were suitable for Ohio forest inventories beyond a total woodland survey has not been made. Therefore, a preliminary evaluation of the potential value of this type data was also considered important to future local use considerations.

Objectives and Scope

The principal objective of this task was to determine whether high-altitude aircraft color infrared imagery is suitable for identifying user-required detailed Ohio forest-land parameters. A second objective was to determine whether such data could be effectively integrated with forest land data derived from LANDSAT imagery and/or digital data to support development of computerized systems.

Initially, the intent was to perform analysis of Trumbull County, Ohio, an area of 159,170 hectares; 34 percent of this area, or 54,118 hectares, is covered by forest land. A NASA overflight requested to provide coverage for the entire area during May/June 1976 resulted in approximately 50 percent coverage of the county, with scattered cumulus clouds obstructing at least 75 percent of the terrain. As a result, sample areas were analyzed in Trumbull, Mahoning, and Franklin Counties.

The following data were used in this analysis:

- High-altitude aerial color infrared positive transparencies taken over portions of Northeast Ohio and Central Ohio on August 12, 1975

- LANDSAT imagery taken over Ohio between August 21, 1972, and September 16, 1976.
- LANDSAT CCT data obtained over Central Ohio on April 4, 1973, and a computer-generated color encoded printout of the four superimposed MSS Bands 4, 5, 6, and 7.
- Aircraft underflight imagery obtained over Franklin County in August 1973 and January 1974 (color and color IR).
- Low level (1000-1500 ft) aircraft, oblique and vertical color and color infrared, 70-mm-format positive transparencies of selected tree stands in Trumbull, Mahoning, and Franklin Counties. This imagery was taken in August, September, and October of 1974 and June 1975.
- Ground truth data and close-up color 35-mm-format photography of selected areas in Trumbull and Franklin Counties.

Methodology

Data analysis was accomplished in the following sequence:

- Selection of suitable forest sample areas
- Collection of ground truth data
- Identification of measurable forest parameters
- Analysis and correlation of data.

Selection of Sample Sites

The criterion for selecting sample sites was primarily based on the availability of high-altitude aircraft and other photographic and reference data required for correlative data analysis. Emphasis was also placed on selecting sites which would be representative of the more dominant tree types in Ohio such as oak and maple.

On this basis, maple forest sites were selected in Trumbull County on the West side of Mosquito Reservoir, in Mahoning County on the banks of Meander Creek Reservoir and in Franklin County in the vicinity of Hoover Reservoir. The sample sites contain representative hard and soft wood types.

Collection of Ground Truth Data

Data were collected on site in Trumbull and Franklin Counties. About 180, 35-mm color photographs were taken to document tree types, tree height, trunk diameter and, in general, prevailing groundcover conditions. These slides were used by the image analyst while interpreting the high-altitude aircraft data.

A data base collected in Franklin and Delaware Counties in 1974 was also utilized.

Identification of Measurable Forest Parameters

Parameters which are used by photointerpreters in subjective and objective forms for describing forested areas are well established. Crown diameter, crown closure, tree height, etc., are some of the quantitative ways photointerpreters measure or derive information regarding wooded areas. Descriptors of dominant colors or tones, on the other hand, are among the more qualitative ways to evaluate or identify forests. These qualitative and quantitative parameters can be readily used by the image analyst in large or medium scale imagery, in which the spatial and spectral resolution permit a clear distinction of individual tree features, i.e., where individual tree crowns are recognizable, and in which tree height may be measured with accuracies of less than a meter.

When high-altitude aerial or satellite photography is being interpreted, individual forest parameters form indistinguishable blends of color, tone and texture; thus, different analysis procedures are required. In areas of "pure" hardwood or softwood stands, identification and evaluation of forested areas by remote sensing has been found to be relatively successful. In Ohio, most forested areas are composed of mixed stands of hardwood, such as oak and hickory or oak and maple, and in some areas pines have been planted in hardwood stands. Thus, the challenge was to identify measurable image characteristics which could be used to derive actual forest conditions. These characteristics had to be of a nature that could be related to automated techniques, since current conventional forest monitoring techniques are relatively costly and time consuming. The following common yardsticks were

therefore used for evaluating high-altitude aerial and satellite data, and for correlating multilevel/multiscale and multidate imagery:

- Spectral Characteristics of Forest Features. Spectral characteristics include the color (in a color photograph) or the tone (in a black and white photograph), as recorded in the photographic image or on digital tapes. On the ground, these characteristics are determined with a spectral radiometer which measures the intensity with which sunlight in the visible and near-infrared portion of the electromagnetic spectrum is reflected by the foliage and tree structure. In this task, spectral evaluations were made to determine whether pertinent forest characteristics can be obtained based on density differences in the photographic image. If such evaluations were successful, then machine processing of forest stands using high-altitude and satellite data would be feasible.
- Spatial Characteristics of Forested Features. Spatial characteristics include the pattern, distribution, shape, etc., by which certain forest features may be derived. Increasingly smaller scales result in a decrease of pertinent spatial parameters usually required to identify information about trees and woodlands. While it is not possible to recognize or measure crown closure or crown diameters in 80-meter-resolution LANDSAT imagery, it was thought that the image characteristics left by many trees in a forest could yield a composite of information from which crown closure could be derived. It was also anticipated that the high-altitude aerial imagery, having a spatial resolution of 1-3 meters, could be used to make some direct measurements such as tree height and canopy diameter.
- Temporal Information. Imagery obtained at different seasons was known to reveal information about forest features which could not be obtained on the basis of spectral and spatial information alone.

Analysis and Correlation of Data

Both conventional photointerpretation and density slicing analysis techniques were used in this task.

Photointerpretation, Including Stereo Analysis. The intent was to extract through visual observations, magnification, additive color viewing, and stereo analysis as many spatial and spectral parameters as possible for interpreting tree types, stand composition, stand height stress, etc. A Richards Multiple Interpretation Module was used, which features

magnification for monocular viewing up to 60X and for stereo viewing up to 30X; a Leitz Orthoplan microscope was also initially used. The Orthoplan featured magnification up to 1000X with an extremely flat field of view, and a built-in 35-mm-format camera for recording the image as viewed by the analyst. The use of high-quality equipment was stressed during the photoanalysis; because the analysis of the satellite data involved photographs covering 28,224 km^2, which appeared concentrated in image areas as small as either 55 x 55 mm or 240 x 240 mm. Thus, an area of 1 km on the ground was represented by an image area of only 0.3 or 1.5 mm in diameter, respectively.

A Wild parallax bar was used for measuring tree height in the high-altitude CIR imagery. Use of this relatively simple equipment resulted in less sensitive height evaluations than is possible using a standard Class I or II photogrammetric mensuration device such as a stereo comparator. A Spectral Data Color Additive Viewer was also used in this task to determine whether the addition or subtraction of color and neutral density filters is helpful for enhancing pertinent forest parameters.

Density Slicing Techniques. A Spatial Data Color Video System 703-32 was used to magnify high-altitude aerial and LANDSAT imagery up to 80X and to density slice selected image areas. The intent was to determine whether areas with hardwood and softwood stands could be distinguished on the basis of the spectral image content. Photographic filters were also used in this process. The device measures density with the accuracy of a microdensitometer. Unlike the microdensitometer, which measures only small spot sizes (typically 1-3 mm), this device measures the entire image at once. An x-y comparator movement permits very precise positioning of the appropriate forest feature. The feature is then displayed as a black and white image on a TV monitor. Using the control console of the system, the operator can select up to 32 density levels for display on the video monitor encoded in color. The overall intent of this portion of the experiment was to determine to what extent density slicing techniques could be used to automatically classify forest features. It was also used to determine if such a technique would result in the identification of parameters not observable by conventional photointerpretation.

Results

A detailed analysis of the high-altitude aerial color infrared imagery and the subsequent correlation with ground truth and LANDSAT data yielded a number of interesting results. Conventional photointerpretive techniques showed spectral and textural (spatial) differences which resulted in the identification of forest areas containing predominantly mixed stands of oak and maple, and pure stands of various pine types. Oak stands and maple stands were characterized primarily by spectral (color) differences, which were confirmed in the low-level aerial and ground photography.

Stereo analysis of the high-altitude data made tree height measurement possible, if the tree was at least 5 meters high. The ability to measure tree height accurately to within ± 2 meters with relatively unsophisticated stereo equipment was demonstrated.

The crown diameters of individual free-standing trees or rows of trees were measurable with an accuracy of 1/4 tree crown diameter. Crown diameters of hardwood trees may be measured, in mixed stands, where spectral differences contrast one type of hardwood tree with another. The crown shapes of maples, for example, were recognizable when surrounded by oaks by magnifying the imagery up to 100 times. At this magnification, a 6-meter crown appears as a circular area of 5-mm diameter in the microscope's objective lens. If a hardwood stand consists entirely of one type of tree, then crown shapes are not distinguishable.

Woodland areas covered primarily by brush and saplings were distinguishable by color, tone, and lack of measurable vegetation height. Cut areas were identified primarily by color and tone, and by their location within or adjacent to woodlands. Hardwood areas undergoing stress, i.e., showing signs of decreasing plant vigor during the normal growing season, could be identified. Such areas appeared greyish in color infrared photography. Areas covered by two or three dead or dying trees could be located in the high-altitude aerial imagery when the imagery was magnified from 60X to 80X, and a high-intensity light source was used to detect subtle differences in color and tone between healthy and stressed trees. It was not determined, however, whether the trees undergoing stress were

[redacted]

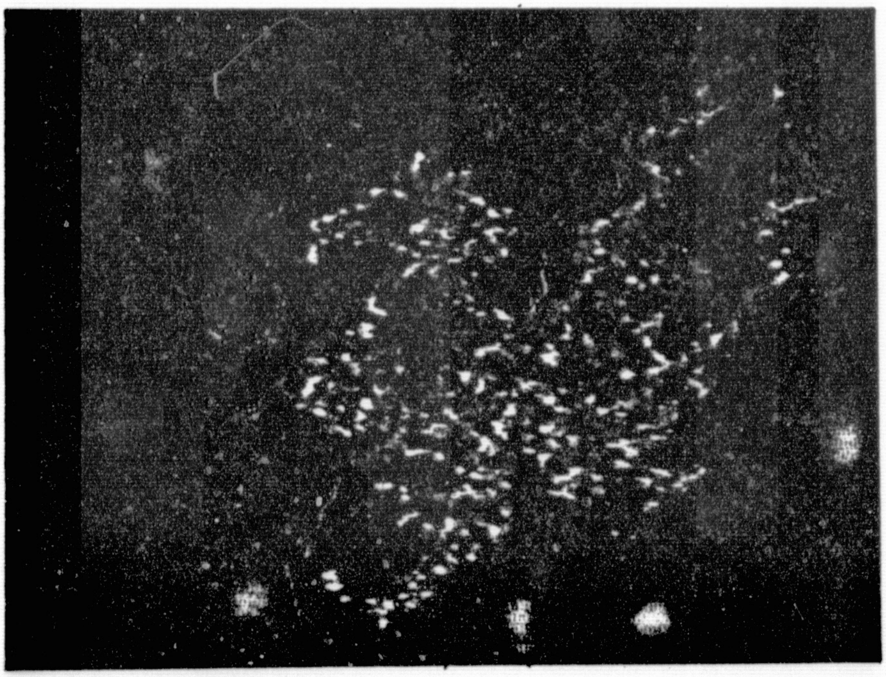
afflicted by grapevine infestation, since the areas affected were located in woodlands which were not readily accessible.

Density slicing of high-altitude aerial color infrared film transparencies resulted in a successful separation by film density of areas covered by hardwoods and softwoods. This would seem to indicate that machine processing on the basis of spectral image content is feasible. Density slicing of the CIR transparencies required the use of a Kodak Type 25 (red) filter for maximum separation of the tree stand types.

Density slicing of LANDSAT imagery, MSS Band 5 (0.6-0.7 μm), covering the same sample woodland areas analyzed in the high-altitude aerial CIR imagery, showed spectral or tone differences similar to those observed in the CIR imagery. This finding suggests that oak and maple hardwood and pine softwood stand mapping may be feasible, provided that analysis is made in conjunction with high-altitude CIR data (see Figure 23). However, it should be noted that machine processing of CIR imagery through density slicing on television-type analysis systems or through initially digitizing the imagery requires that corrections be made to eliminate the vignetting effect noticeable in all the high-altitude imagery.

Computer-generated color composites of all four LANDSAT MSS bands using CCT data collected prior to the growing season in Ohio showed strong tonal differences in woodland areas which appear to indicate differences in tree species and stand condition, (Figure 24). The large arrows in Figures 24 and 25 show a woodland area covered by a dense stand of silver maple and shag bark hickory trees, which were estimated to be 50 to 60 feet in height, as observed from ground level. The area appeared primitive and unmanaged, with dead branches litering the ground and thousands of 2 to 6-inch saplings crowding those areas not covered by the mature trees. The small arrows show a woodland area, consisting primarily of oak, some maple and other hardwood trees, which appears very well managed, with little debris covering the ground. A comparison of winter photography (scale 1:40,000) of the two forest stands revealed that the tree canopies without leaves appeared so dense in the former stand that individual tree trunks could not be observed. In the latter stand, individual tree trunks of the oaks could be seen in those areas away from the principal point of the photographic image. This finding suggests that LANDSAT winter and early spring photography may be suitable

a. HIGH-ALTITUDE AIRCRAFT COLOR IR
(AUGUST 12, 1975)



b. LANDSAT (BAND 5, AUGUST 21, 1972)

FIGURE 23. COMPARISON OF LANDSAT AND HIGH-ALTITUDE AIRCRAFT IMAGERY SHOWING SPECTRAL DIFFERENCES BETWEEN MAPLE AND OAK STANDS. (GREEN REPRESENTS PREDOMINANTLY MAPLE TREES; RED IS PREDOMINANTLY OAK TREES.)

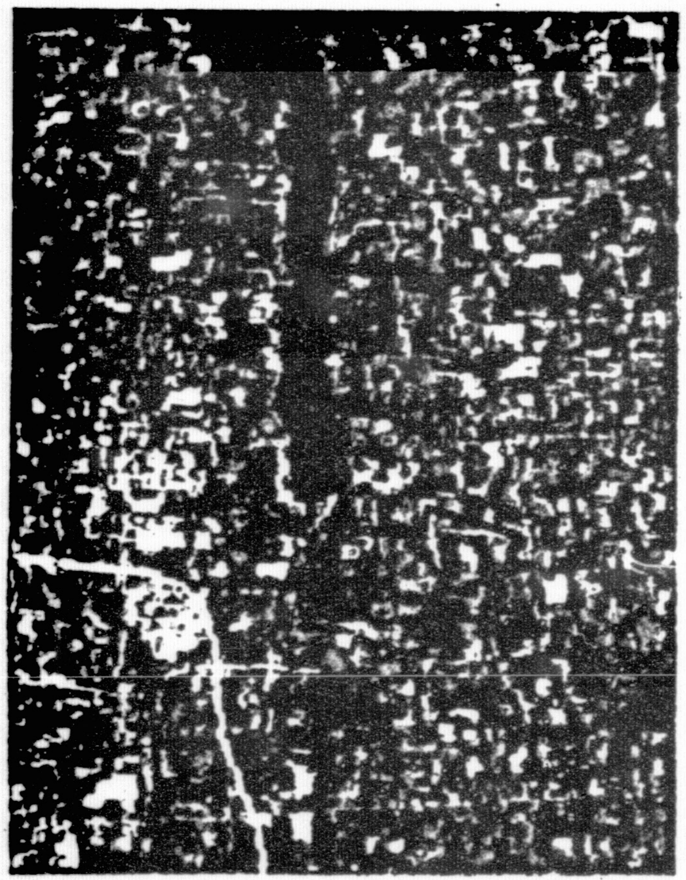


FIGURE 24. COMPUTER GENERATED LANDSAT COLOR COMPOSITE (4 MSS BANDS) FOR APRIL 14, 1973 SHOWING STRONG TONAL DIFFERENCES IN SAMPLE WOODLAND AREAS IN FRANKLIN COUNTY, OHIO.

FIGURE 25. HIGH ALTITUDE AIRCRAFT CIR IMAGERY OF AUGUST 12, 1975) SHOWING THE SAME GENERAL AREA IN THE LANDSAT PHOTO. (NOTE THAT DESPITE THE SUPERIOR SPATIAL RESOLUTION, THE TONAL DIFFERENCES SHOWN IN THE LANDSAT IMAGERY ARE NOT VISABLE IN THE AERIAL IMAGERY.

for identifying forest parameters with regard to composition, maturity and condition not observable in imagery obtained during the normal growing season. It also emphasizes the need to explore and exploit the temporal aspects of LANDSAT data.

Conclusions and Recommendations

Analysis of high-altitude aircraft infrared color photography has shown that an inventory of Ohio woodland by stand composition, maturity, and condition is feasible. Analysis may be performed by conventional photo-interpretation techniques to establish detailed forest parameters such as tree height, species composition, crown diameter and, by calculation, tree trunk diameter. Such detailed analysis always requires close correlation with information collected on the ground in preselected areas.

Machine processing, such as density slicing techniques, may then be used for delineating forest areas with common spectral characteristics. These spectral characteristics reflect actual differences in forest conditions, such as those caused by differences in forest composition. Since density slicing of photographic transparencies has shown that different forest compositions and certain stages of maturity can be delineated, it can be safely assumed that digitization and subsequent computer analysis of the photographic image is also feasible.

Analysis of LANDSAT data in conjunction with aircraft data showed the following results: forested areas on aircraft imagery which were density sliced, and which showed density anomalies due to tree stand composition, showed very similar density anomalies in LANDSAT imagery. Other density measurements on aircraft imagery which reflected forest land conditions also could be delineated in LANDSAT imagery. This suggests that despite the complexity of Ohio's mixed forest stands, an analysis of LANDSAT data using conventional photointerpretation techniques to establish detail, and computerized techniques to map large county-sized areas, is feasible. The detailed analysis would have to be based on high-altitude aircraft imagery and extensive ground truth in preselected areas. Analysis of the aircraft imagery would be performed through conventional photo-interpretive methods; transfer of the analyzed data could then be

accomplished by digitization of the imagery and integration with the LANDSAT data.

Much emphasis should be placed on the analysis of temporal data as recorded in sequential LANDSAT and aircraft data. Careful examination of such temporal data has shown that the data provided information about stand conditions and maturity which cannot be obtained in any other way.

Use/User Implications

The analysis of LANDSAT and Skylab data had previously shown that total inventories of forest lands in Ohio are feasible. Such inventories have resulted in improved acreage data than previously accomplished using conventional regression techniques. It has been observed, however, that inventories are frequently attempted which are far too ambitious in terms of the inherent technical limitations of the satelite data and too limited in the amount of effort users are willing to commit to such inventories. Until the launching of LANDSAT I in July 1972, woodland inventories were typically accomplished with 1:24,000-scale aerial panchromatic imagery and/or ground surveys. The availability of satellite data which record woodland areas in 185 x 185-km scenes has led many users to believe that the same techniques used in the interpretation of a photograph covering 5.5 x 5.5 km can also be readily applied in the interpretation of the satellite data. However, it is simply not possible to apply the same interpretation techniques to some 1100 aerial photographs each covering approximately 30 km^2 which are required to cover the same area as a single satellite photograph covering more than 34,000 km^2. Image parameters such as spectral and spatial characteristics cannot often be related on a 1:1 basis, and frequently vary widely within one given scene. Thus, the tendency to overgeneralize to achieve a quick and inexpensive analysis has resulted in inaccurate and discouraging data which forest planners and managers simply cannot use.

This task has confirmed that a comprehensive woodland inventory of Ohio forest land to establish and monitor total stands, predominant stand composition and maturity in county-sized areas at scales no smaller than 1:63,360 is feasible using LANDSAT temporal data, aircraft and ground truth data of selected areas.

Bibliography

"Relevance of ERTS-1 Data to the State of Ohio", Ohio Department of Economic and Community Development (October 1974).

Utilizing Skylab Data in On-Going Resource Management Programs in the State of Ohio", Ohio Department of Economic and Community Development (November 1975).

"The Timber Resources of Ohio", USDA Forest Service Resource Bulletin NE 19 (1970).

"Plan of Action", Crossroads RC&D (May 1973).

Spurr, S. H., Photogrammetry and Photointerpretation (Section on Applications for Forestry), Second Edition (1960), pp 347-444.

Manual of Remote Sensing, Volume I, Chapter XVII: Forest Lands Inventory and Assessment, American Society of Photogrammetry (1975), pp 1353-1416.